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# ENAMAP-1 (Eastern North American Model of Air Pollution) Long-Term SO2 and Sulfate Pollution Model: Further Application to Eastern North America

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# ENAMAP-1 LONG-TERM $SO_2$ AND SULFATE POLLUTION MODEL

## Further Application to Eastern North America

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A study was carried out to apply and test the Eastern North American Model of Air POllution (ENAMAP-1), a regional trajectory-type model that is an adapted version of the European Model of Air Pollution (EURMAP-1) developed by SRI International (SRI) for the Federal Republic of Germany. The ENAMAP-1 model calculations were based on all available wind and precipitation data and on specialized emission data prepared for the Sulfate Regional Experiment (SURE) program.

The ENAMAP-1 model has been tested to determine the variability of the model's seasonal calculations caused by year-to-year changes in wind and precipitation patterns. Sulfur emission data for 1977 were used with meteorological data and annual sulfur concentrations, depositions, and regional exchanges. The calculated results appeared to be in reasonably good agreement with the available air quality measurements. The effects of yearly variations in the transport winds were most noticeable in the monthly $SO_4^=$ concentration patterns and in the $SO_4^=$ wet-deposition fields; the latter also showed strong sensitivity to yearly variations in precipitation.

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# ABSTRACT

This report describes the results of Phase II of a study to apply and test the *E*astern *N*orth *A*merican *M*odel of *A*ir *P*ollution (ENAMAP-1), a regional trajectory-type model that is an adapted version of the European Model of Air Pollution (EURMAP-1) developed by SRI International (SRI) for the Federal Republic of Germany. The ENAMAP-1 model calculations are based on all available wind and precipitation data and on specialized emission data prepared for the Sulfate Regional Experiment (SURE) program.

In Phase I of the study, ENAMAP-1 was extensively applied over the eastern United States and southeastern Canada using emission and meteorological data for 1977 to investigate and evaluate the interregional transport and deposition of sulfur. In Phase II of the study, the ENAMAP-1 model has been further tested to determine the variability of model's seasonal calculations caused by year-to-year changes in wind and precipitation patterns. Sulfur emission data for the year 1977 were used with meteorological data of four recent years (1975-1978) and model calculations were made of the monthly and annual sulfur concentrations, depositions, and regional exchanges. The calculated results appear to be in reasonably good agreement with the available air quality measurements. The effects of yearly variations in the transport winds were most noticeable in the monthly $SO_4^=$ concentration patterns and in the $SO_4^=$ wet-deposition fields; the latter also showed strong sensitivity to yearly variations in precipitation.

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# SECTION 1

# INTRODUCTION

Under contract to the U.S. Environmental Protection Agency (EPA), SRI International (SRI) developed and evaluated an *Eastern North American Model of Air Pollution* (ENAMAP) (Bhumralkar et al., 1980).[*] The ENAMAP-1[†] model, which is a modified version of the SRI-developed European Model of Air Pollution (EURMAP)[‡] was specifically designed to study long-term transboundary air pollution processes over eastern North America. The model can be used to calculate monthly, seasonal, and annual values of sulfur concentrations and depositions and to quantify interregional exchanges of airborne sulfur between various selected Canadian and EPA regions. ENAMAP-1 has been shown to be highly suitable for application to assess the long-term transboundary sulfur pollution problem in eastern North America, because of its realistic treatment of precipitation scavenging and wet deposition and its consideration of both $SO_2$ and $SO_4^=$ emissions over a very large region.

This report describes the results of a study funded by EPA with the objectives of applying the ENAMAP-1 model to further test the model and to study the variability of the model's seasonal calculations of sulfur concentrations and depositions due to year-to-year changes in the wind and precipitation patterns. Section 2 of this report reviews the basic structure of the ENAMAP-1 model with respect to model grid boundaries and other variables. Section 3 presents a review of the data base, including the air-quality, emission, and meteorological data used with ENAMAP-1. Sections 4 through 7 describe the monthly and annual results obtained from ENAMAP-1 using weather data for the four years 1975, 1976, 1977, and 1978 and sulfur emission data for 1977. The results for the winter (January) months are shown in Section 4 and the results for the summer (July or August) months are shown in Section 5. The results for the transitional months (i.e., April and October) are presented in Section 6; the annual results are shown in Section 7. The results presented in these sections (4 to 7) are shown in graphic form for $SO_2$ and $SO_4^=$ concentrations and $SO_4^=$ wet depositions, and tabular form for the interregional exchanges of sulfur (S).[§] Section 8 presents the summary and conclusions of the study.

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[*] References are listed at the end of this report.

[†] SRI is currently developing an improved version of ENAMAP-1 which will be designated ENAMAP-2. This will include, among other things, effects of complex terrain and emissions released at higher elevations.

[‡] EURMAP-1 was developed by SRI under the sponsorship of the Environmental Agency (Umweltbundesamt) of the Federal Republic of Germany (FRG). For a detailed description of this model, see Johnson et al. (1978).

[§] Additional graphical results from the ENAMAP-1 calculations in this study are given in the appendices.

## SECTION 2

## REVIEW OF THE ENAMAP-1 MODEL

ENAMAP-1 is a practical air pollution model designed to have minimum computational requirements for use in making long-term calculations economically, while at the same time offering acceptable realism in simulating the most important processes involved in the transboundary air-pollution problem. The ENAMAP-1 model can be used to calculate monthly, seasonal, and annual $SO_2$ and $SO_4^=$ air concentrations; $SO_2$ and $SO_4^=$ dry and wet deposition patterns; and interregional exchanges resulting from the $SO_2$ and $SO_4^=$ emissions over eastern North America. The model uses long sequences of historical meteorological data as input, retaining all the original temporal and spatial detail inherent in the data.[*]

In the ENAMAP-1 model, discrete puffs of $SO_2$ and $SO_4^=$ are assumed to be emitted at equal time increments from cells of an emission grid. This type of treatment provides a realistic representation of area sources. For a point source, it assumes that the pollutant expands initially to fill uniformly the volume of the cell from the point within the cell where the source is actually located. [In this application, seasonal emission data were conveniently available on an 80- by 80-km Universal Transverse Mercator (UTM) grid.] For each of the emission cells, the average annual or seasonal emissions are divided into discrete emission puffs released at 12-hour intervals and tracked at 3-hour time steps, until either they move outside the region of analysis or their concentrations drop to an insignificant level (10 tons of $SO_2$ and 1 ton of $SO_4^=$). The individual puffs are transported according to a transport wind field that is derived objectively from the available upper-air wind observations.

Since diffusion on the regional scale is not as significant as the transport and removal processes, very simple treatments of vertical and horizontal diffusion have been used. Upon release, each puff is assumed to undergo instantaneous vertical diffusion to give uniform concentration in the layer between the surface and the top of the mixing height. Horizontal diffusion is treated by allowing the area of the puff to increase linearly with time on the basis of Fickian diffusion, assuming a horizontal eddy diffusivity of 36 $km^2h^{-1}$. During the transport of the puff, the model assumes that the pollutant concentration within a puff is always uniform.

The amount of pollutant mass that is removed from a puff during each 3-hour time step is dependent on the specified dry and wet deposition rates that are used; these amounts are deposited within the appropriate 70- by 70-km cells of the receptor grid. At each time step, a fraction of the $SO_2$ is transformed to $SO_4^=$ at the specified transformation rate. Figure 1 shows the eastern sector of the North American continent over which the ENAMAP-1 model has been applied. This sector covers the region between 30°N and 50°N latitudes and 105°W and 65°W longitudes. Figure 1(a) shows the EPA regions and subregions used in this study; southern

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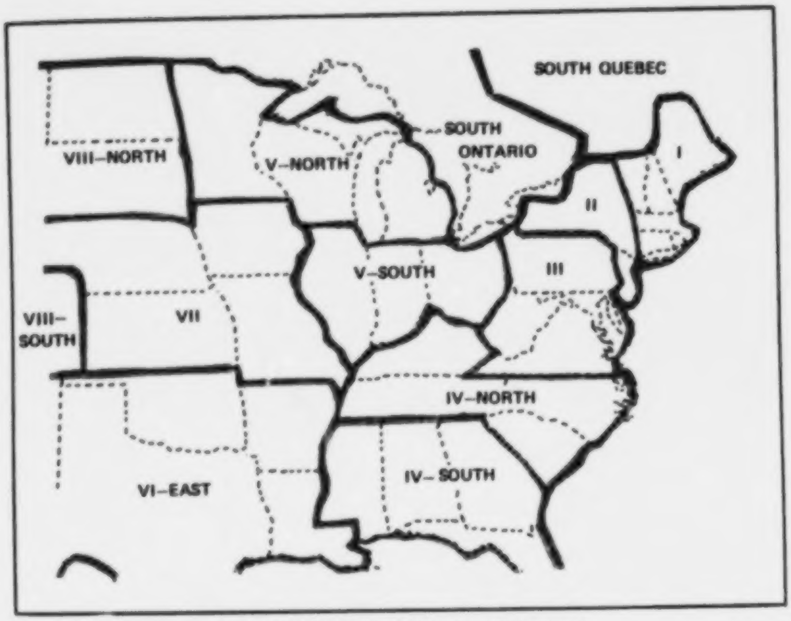
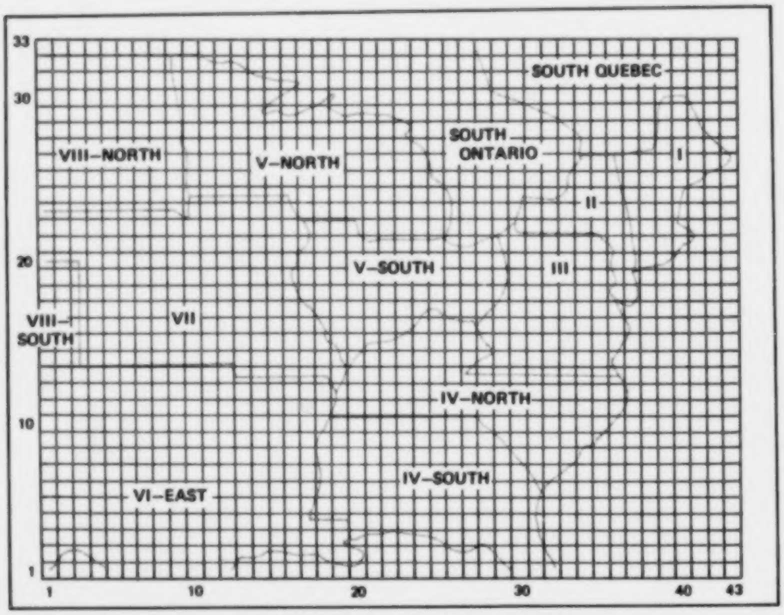
[*] A more detailed description of the long-term ENAMAP-1 model and its application to studies of interregional sulfur transport and deposition is given in Bhumralkar et al. (1980).



(a) EPA REGIONS USED IN THIS STUDY



(b) EMISSION GRID AND MODEL DOMAIN

Figure 1. Eastern North American domain and EPA regions used in this study

portions of Quebec and Ontario provinces of Canada are also included. Figure 1(b) shows the model receptor grid. Each receptor-cell measures 70 by 70 km. The pollutant depositions are accumulated and concentrations are averaged in these receptor cells. The values for the basic model elements that have been used are listed in Table 1. These values are based on reviews of recent field, laboratory, and theoretical studies and on evaluation studies (Mancuso et al., 1978).

TABLE 1. ELEMENT VALUES USED
IN THE ENAMAP-1 APPLICATION TO EASTERN NORTH AMERICA

| Element | Values |
|---|---|
| Emission rate | Data provided by season |
| Transport windspeed (V) ($ms^{-1}$) and direction ($\theta$) | Derived by integrating winds over boundary layer |
| Mixing height (km) | |
| $h = h_o + \zeta\Lambda$* | $h_o = 1.3$<br>$\zeta = -0.15$ |
| $SO_2$ deposition rates ($hr^{-1}$) | |
| Dry | 0.037 |
| Wet | 0.28R† |
| $SO_4^=$ deposition rates ($hr^{-1}$) | |
| Dry | 0.007 |
| Wet | 0.07R† |
| $SO_2/SO_4^=$ transformation rate ($hr^{-1}$) | 0.01 |

*$\Lambda$ = +1 in winter, -1 in summer, and 0 in spring and fall.

†R is the precipitation rate in $mm/hr^{-1}$.

In this study, the basic model was run for the months of January, April, July, and October of the years 1975, 1976, and 1978 and January, April, August, and October of 1977 using the meteorological data for each year. The emission data of 1977 were assumed to apply for all four years, mainly because no data base of similar quality and resolution was available for the years 1975 and 1976. The particular months were selected in order to examine the seasonal variations in the results. [In 1977, August rather than July was chosen as representative of the summer because of the availability of a greater amount of Sulfate Regional Experiment (SURE) air quality data.] For each of the four months of each of the years, fields of $SO_2$ and $SO_4^=$ concentrations, dry depositions, and wet depositions resulting from the $SO_2$ emissions were calculated, stored, and displayed graphically. Interregional exchange tables were also generated.

Annualized depositions for each of the years were estimated by assuming that the results for each of the four months were representative of seasonal values, totalling the four monthly deposition values, and multiplying by three. Similarly, estimates of annual average concentrations were obtained by averaging values for the four months.

# SECTION 3

## REVIEW OF THE DATA BASES

The ENAMAP-1 model uses three types of data--meteorological (winds and precipitation), emission ($SO_2$ and $SO_4^=$), and air quality ($SO_2$ and $SO_4^=$ concentration measurements). The main purpose of this study has been to determine the effects of weather on the ENAMAP-1 calculations. Therefore, actual meteorological data for the years 1975 through 1978 have been used, with the emission data for the year 1977, permitting a direct determinination of the effects of weather on the results. However, the calculated results are thus strictly correct only for the year 1977, and the comparisons with the air quality data are most valid for that year. A detailed description of the data bases is given by Bhumralkar et al. (1980); a brief review is given below.

### Meteorological Data

Historical meteorological data for this study (upper-air wind data for the United States and precipitation data for the United States and Canada) were obtained from the National Climatic Center (NCC) in Asheville, North Carolina. The basic analyses were made with a computer program that generated both transport winds and precipitation amounts at 3-hourly intervals for the 70- by 70-km weather grid of ENAMAP-1. The precipitation data include detailed data from about 2,000 U.S. stations, and the analyzed values are expressed as rainfall rates in mm/hr, and are used directly in the wet deposition calculations.

### Emission Data

Emission data have been collected for a number of years and maintained by the National Emissions Data Systems (NEDS) of the EPA. The NEDS data cover the entire U.S. portion of the ENAMAP-1 study area and provide relatively high spatial resolutions. Specialized emission data have also been prepared for the SURE program. These data are complete for sources existing in July 1977 and effectively represent emissions for the 1977 time period. This SURE emission data base is essentially a refinement of the NEDS data base; that is, the NEDS data are updated and screened for errors and inconsistencies, especially with respect to electric power plants.

The 1977 seasonal emission data base that was used in this study* was based wherever possible on the specialized emission data of the SURE program. The SURE data, which are arranged on an 80- by 80-km UTM grid, cover almost the entire area considered in this study except for Texas and the Great Plains states. For this westernmost portion of the ENAMAP-1 domain, gridded emission data were supplied by NEDS.

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*Graphical displays of these emissions were shown in Bhumralkar et al. (1980).

### Air Quality Data

Air quality data appropriate for validation of ENAMAP-1 were obtained from two different data bases: the SURE air quality data and the Storage and Retrieval of Aerometric Data (SAROAD). The SURE data are not as extensive spatially as the SAROAD data, but they are relatively free of urban bias (Perhac, 1978). The SURE data were somewhat sparse geographically and were available for only the last two years of our study. Thus, they were augmented by SAROAD data that were screened to reject sites most likely to have a local-source influence or values that were obviously in error. However, the selected sites included population-oriented surveillances and special study sites that could contain data reflective of local conditions. Also, the SAROAD $SO_4^=$ measurements were very sparse temporally, and a monthly average would involve at most two days of measurements resulting in unrepresentative values. The air quality data were used to calculate monthly average $SO_2$ and $SO_4^=$ concentrations for 140- by 140-km grid squares.

# SECTION 4

# RESULTS FOR JANUARY (1975-1978)

## $SO_2$ Concentrations

The calculated and measured $SO_2$ concentrations ($\mu g/m^3$) for the month of January for each of the four years 1975, 1976, 1977, and 1978 are shown in Figures 2 through 5.* These figures also show the monthly mean wind vector fields of the 3-hourly winds used for transporting the puffs. Results for the calculated January $SO_2$ dry depositions, which are proportional to the calculated $SO_2$ concentrations, are shown in Appendix A.

*January 1975*—The mean wind field for January 1975 [Figure 2(c)] shows a rather interesting wave structure across the United States with southerly flow onto the Midwest (especially Illinois) and an anticyclonic vortex over the Southeast. This January wind pattern is distinctly different from those for 1976, 1977, and 1978. The calculated $SO_2$ concentration field [Figure 2(a)] shows maximum concentrations ( $> 64$ $\mu g/m^3$) near Pittsburgh, and other high concentration centers ( $> 32$ $\mu g/m^3$) near the cities of New York, Cincinnati, Cleveland, Detroit, Sudbury (Ontario), and in eastern Kentucky--generally corresponding with high emission areas. Relatively high calculated $SO_2$ concentrations also appear near Atlanta and Mobile. A calculated pocket of relatively low values ( $< 16$ $\mu g/m^3$) crosses central Illinois, Indiana, and Ohio. This appears to have been caused by the transport of low emissions from the Arkansas area and the removal of pollutants from the air by heavy precipitation just prior to its entering the central Illinois-Indiana-Ohio area.†

The measured values for the January 1975 $SO_2$ concentrations are shown in Figure 2(b). A comparison of the calculated and measured values shows that:

- The calculated $SO_2$ concentration pattern has a maximum peak value of 72 $\mu g/m^3$ over the Pittsburgh area. This compares favorably with the measured values that reach 87 $\mu g/m^3$ in this area, although the measured peak value appears to be displaced slightly southward.
- The high calculated $SO_2$-concentrations over the Pittsburgh, Detroit, and New York areas generally coincide with the location of relatively high measured values. However, the measured concentrations tend to show higher values throughout the Northeast, whereas the calculated results do not. This effect is not as noticeable in later years and possibly is seen because emissions representative of 1977 were used as the bases for these 1975 calculations.

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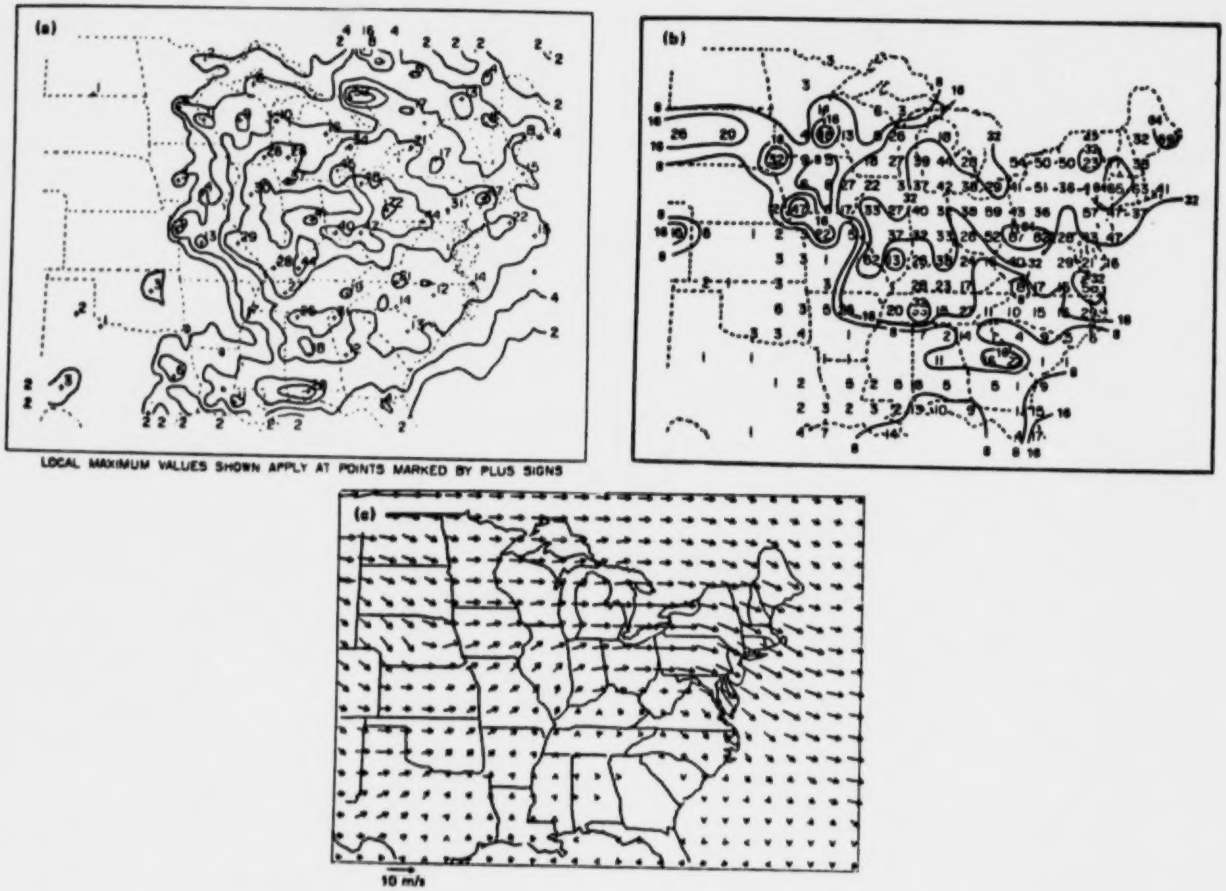
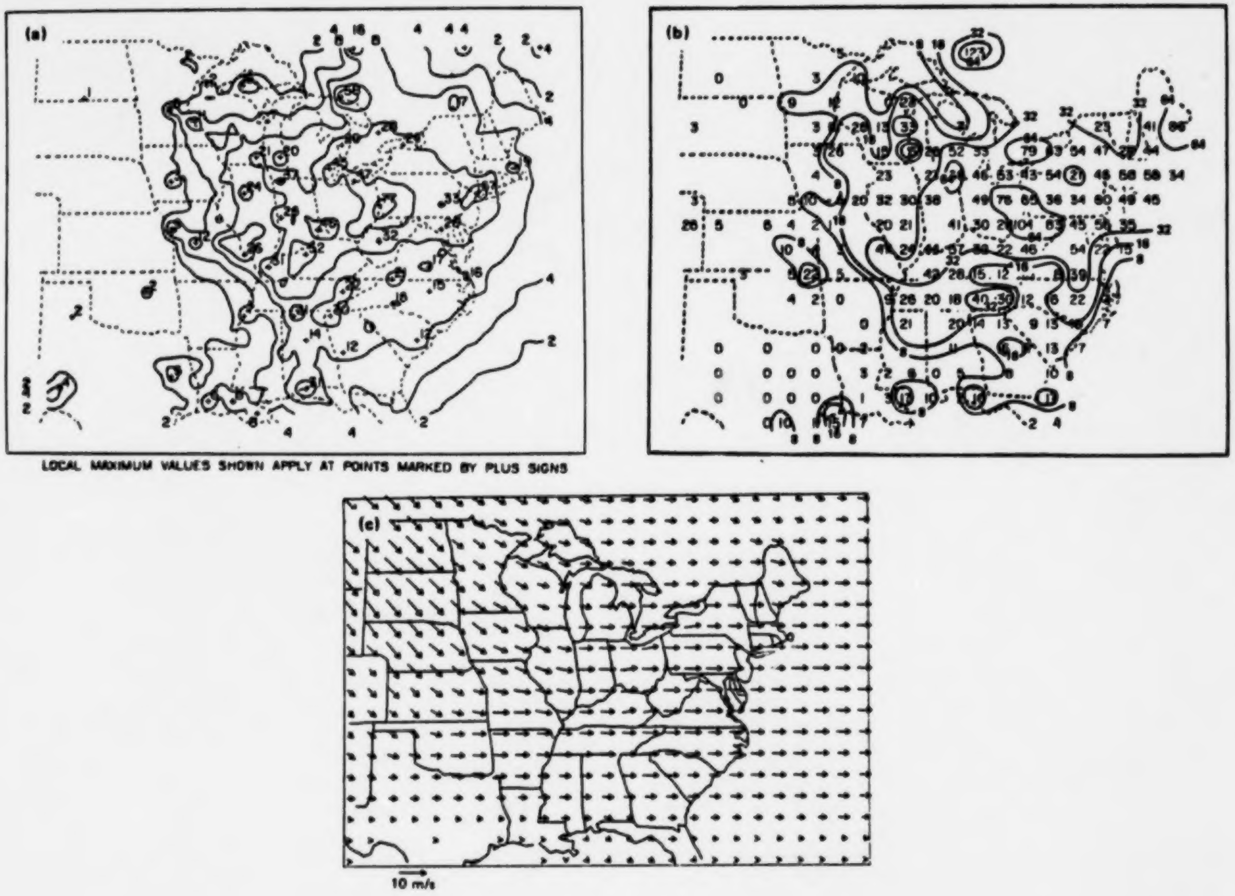
*The calculated values are depicted by isolines that are machine-drawn at values of 2, 4, 8, 16, 32, ... ($\mu g/m^3$), with local maxima indicated at "+" marked locations. The measured values are depicted by isolines that are hand-drawn to values averaged over 140- by 140-km squares. (Hand-drawn isolines are not shown for values below 8 $\mu g/m^3$).

†The precipitation chart is shown later in Figure 10(b).



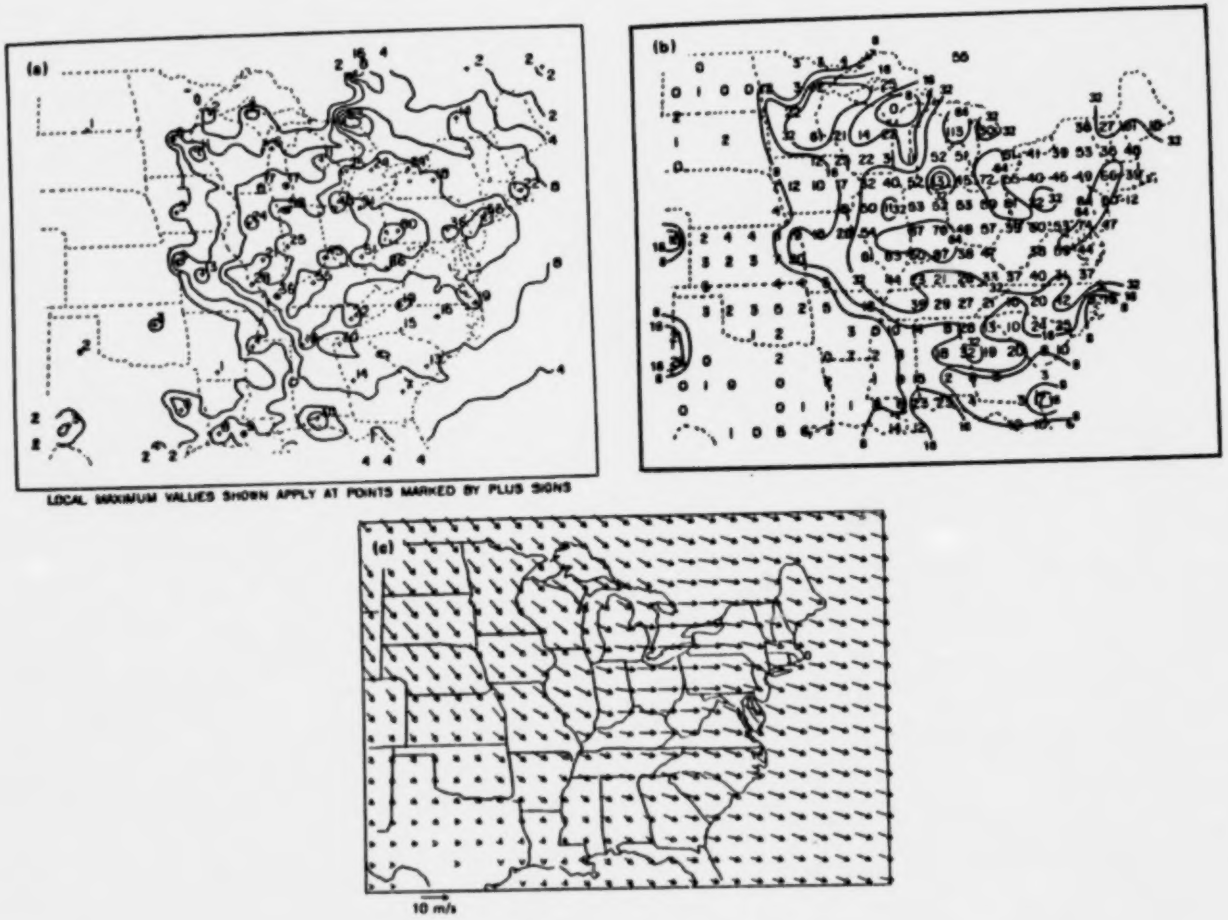
LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

Figure 2. $SO_2$ concentrations ($\mu g/m^3$) for January 1975.
(a) calculated, (b) measured, (c) mean monthly transport winds.



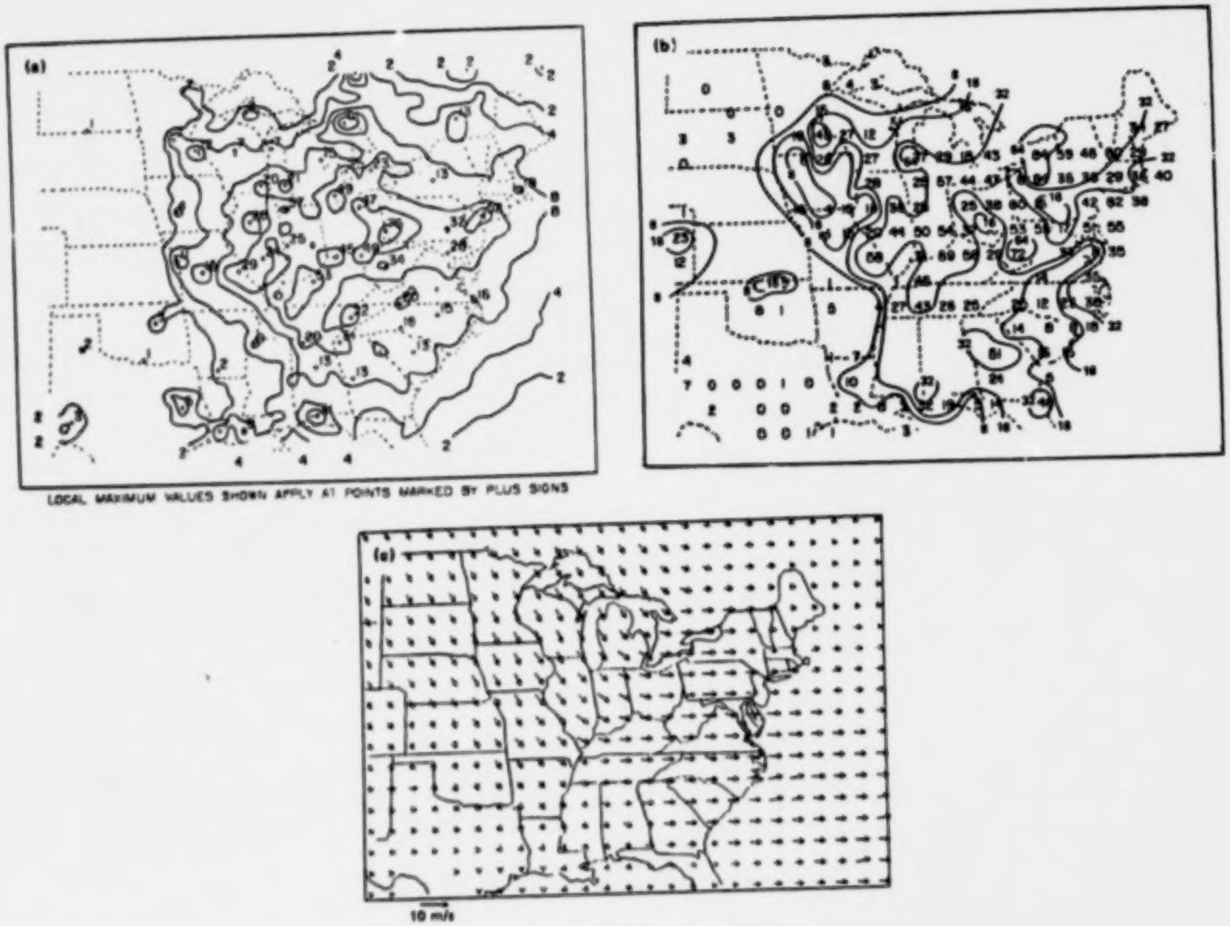
LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

Figure 3. $SO_2$ concentrations ($\mu g/m^3$) for January 1976.
(a) calculated, (b) measured, (c) mean monthly transport winds.



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

Figure 4. $SO_2$ concentrations ($\mu g/m^3$) for January 1977.
(a) calculated, (b) measured, (c) mean monthly transport winds.



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

Figure 5. $SO_2$ concentrations ($\mu g/m^3$) for January 1978.
(a) calculated, (b) measured, (c) mean monthly transport winds.

- The low calculated-concentration region over the Illinois-Indiana-Ohio area does not appear in the measured data, nor do the high calculated values over southern Ohio, western Kentucky, and northern Alabama. Again, this is quite possibly attributable to the use of 1977 emission data.
- The measured concentrations show much higher values over St. Paul and St. Louis than those shown by the calculated results. A number of high isolated measured values (from 10 to 40 $\mu$g/m$^3$) in the western part of the domain (e.g., South Dakota, Iowa, and Colorado) lie in regions where the calculated values of $SO_2$ concentrations are below 2 $\mu$g/m$^3$. These discrepancies are probably caused by the measurement's being located close to local sulfur emission sources and being unrepresentative of regional values. These isolated high concentrations in the west did not appear in the measurements of subsequent years--possibly because data from these sites were rejected or the monitoring efforts at the sites were discontinued. Also, it should be realized that the model considers no emissions west of 105° W. In reality, such emissions do exist and would have some impact on the western part of the model domain.

*January 1976*—The wind pattern for the January 1976 period [Figure 3(c)] is noticeably different from the wave structure of January 1975 [Figure 2(c)]. The field has a much simpler pattern of northwesterly winds in the western half of the domain and westerly winds over the eastern half of the domain. The $SO_2$ concentrations for the January 1976 period [Figure 3(a)] are similar to those for January 1975 [Figure 2(a)], but differ in detail because of the differences in the transport winds. There is a broader area of slightly higher concentrations centered over the New York area, apparently because of lighter transport winds during January 1976. The 34-$\mu$g/m$^3$ isoline for January 1976 extends only to the eastern border of Illinois; for January 1975 it extends farther west to the western border of Illinois, also apparently because of different average wind speeds. The strip of relatively low concentrations across central Illinois, Indiana, and Ohio that appears in the $SO_2$ concentration field of January 1975 does not appear in the January 1976 field.

The measured $SO_2$ concentration values for January 1976 [Figure 3(b)] are noticeably larger than those for January 1975 [Figure 2(b)], but they have many similarities; for example, they both show peak values near Pittsburgh, New York, Detroit, Buffalo, and St. Louis. The measured data for January 1976 appear to agree better with the calculated results, probably because the 1977 emission data are more applicable for this period. For example, the January 1976 measured data show relatively high values for $SO_2$ concentrations over western Kentucky and eastern Tennessee, consistent with the calculated results and emission data. However, the calculated $SO_2$ concentration values are generally lower than the measured. Also, there is a 123-$\mu$g/m$^3$ measured value in Canada and some large values in the western area of the domain (e.g., a 26-$\mu$g/m$^3$ value in eastern Colorado and a 22-$\mu$g/m$^3$ value near Tulsa, Oklahoma)--these are not seen in the calculated results, probably because the measurements are biased by local sources.

*January 1977*—The winds for January 1977 [Figure 4(c)] are very similar to those for 1976 [Figure 3(c)], except that there is a slight northerly component off the East Coast. Because of this similarity in the transport winds, the calculated $SO_2$ concentration patterns for January 1977 [Figure 4(a)] are also very similar to those calculated for January 1976.

The measured $SO_2$ concentrations for January 1977 are very similar to those for January 1976. However, the emission data are actually those for the year 1977, so the comparison of the calculated and measured values for January 1977 is more meaningful than those for the other years. The $SO_2$ concentration patterns of the model calculations compare quite favorably with the measured ones, especially in areas of high concentration. For example, both the calculated and measured values show maxima in the New York area, as well as in the Pittsburgh area; these maxima are also comparable. However, as in January 1976, the calculated values are generally lower than the measured values; this is believed to be partially caused by the use of mixing-height values in the model that were too high.

There are some significant differences between the calculated and measured concentrations at some specific locations. In the northwestern part of the area, measured values of 42 and 61 $\mu g/m^3$ are found along the Minnesota/Wisconsin border, while the maximum calculated value along this border (near St. Paul) is 11 $\mu g/m^3$. There is also a 113 $\mu g/m^3$ observation near Flint, Michigan, that is not depicted by the calculated values. Another noticeable discrepancy between the calculated and measured concentrations occurs at the western boundary of the model domain, where measured values exceed 16 $\mu g/m^3$ in eastern Colorado and New Mexico. However, all these measured data belong to a population-oriented classification of the SAROAD data, and may not be representative of regional values.

*January 1978*—The January winds for 1978 [Figure 5(c)] are very similar to those for 1977 and 1976, except that the wind magnitudes are somewhat lighter and have a slightly more dominating northerly component in the western half of the domain. Again, because of this similarity in winds, the calculated $SO_2$ concentrations for January 1978 [Figure 5(a)] are very similar to those calculated for January 1977 [Figure 4(a)] and January 1976 [Figure 3(a)].

The measured $SO_2$ concentrations for January 1978 [Figure 5(b)] show some noticeable differences from the measured data for the previous years, and thus differ from the calculated results [Figure 5(a)]. The Pittsburgh region does not appear to be as dominating as in previous years, but there are now higher measured values in West Virginia and eastern New York, and lower values in Ohio. These difference may be attributable to significant changes in the actual sulfur emissions for the year 1978; ENAMAP-1 calculations based on an updated emissions inventory for 1978 would reveal if this were true.

### $SO_4^=$ Concentrations

The calculated and measured $SO_4^=$ concentrations ($\mu g/m^3$) for January of each of the four years 1975, 1976, 1977, and 1978 are shown in Figures 6 through 9. Since the $SO_4^=$ concentration fields are strongly dependent on the transport wind field, the mean monthly wind charts are repeated in these figures for ease of comparison [e.g., Figure 6(c) is identical to Figure 2(c)]. It should be realized that monthly average wind vectors can be misleading and not always representative of the actual daily weather. Results for the calculated January $SO_4^=$ dry depositions, which are proportional to the calculated $SO_4^=$ concentrations, are shown in Appendix A.

*January 1975*—The calculated $SO_4^=$ concentration pattern for January 1975 [Figure 6(a)] is a very interesting one. A strip of higher $SO_4^=$ concentrations ( $> 8$ $\mu g/m^3$) extends across the Northeast, strongly reflecting the anticyclonic pattern of the wind field. This $SO_4^=$ field shows relatively low values in the central Illinois-Indiana-Ohio area, as did the $SO_2$ field; however, the low $SO_4^=$ concentrations also extend across Illinois into the western Kentucky-Tennessee area.

Comparison of the calculated and measured $SO_4^=$ concentrations for January 1975 [Figure 6(b)] is difficult because of the lack of an extensive monitoring network. However, where there are data, the comparison is generally very good. For example, the strip of high calculated values mentioned above, which extends across the southern tips of the Great Lakes and across Pennsylvania, appears to be depicted by the measured data. The measured data show

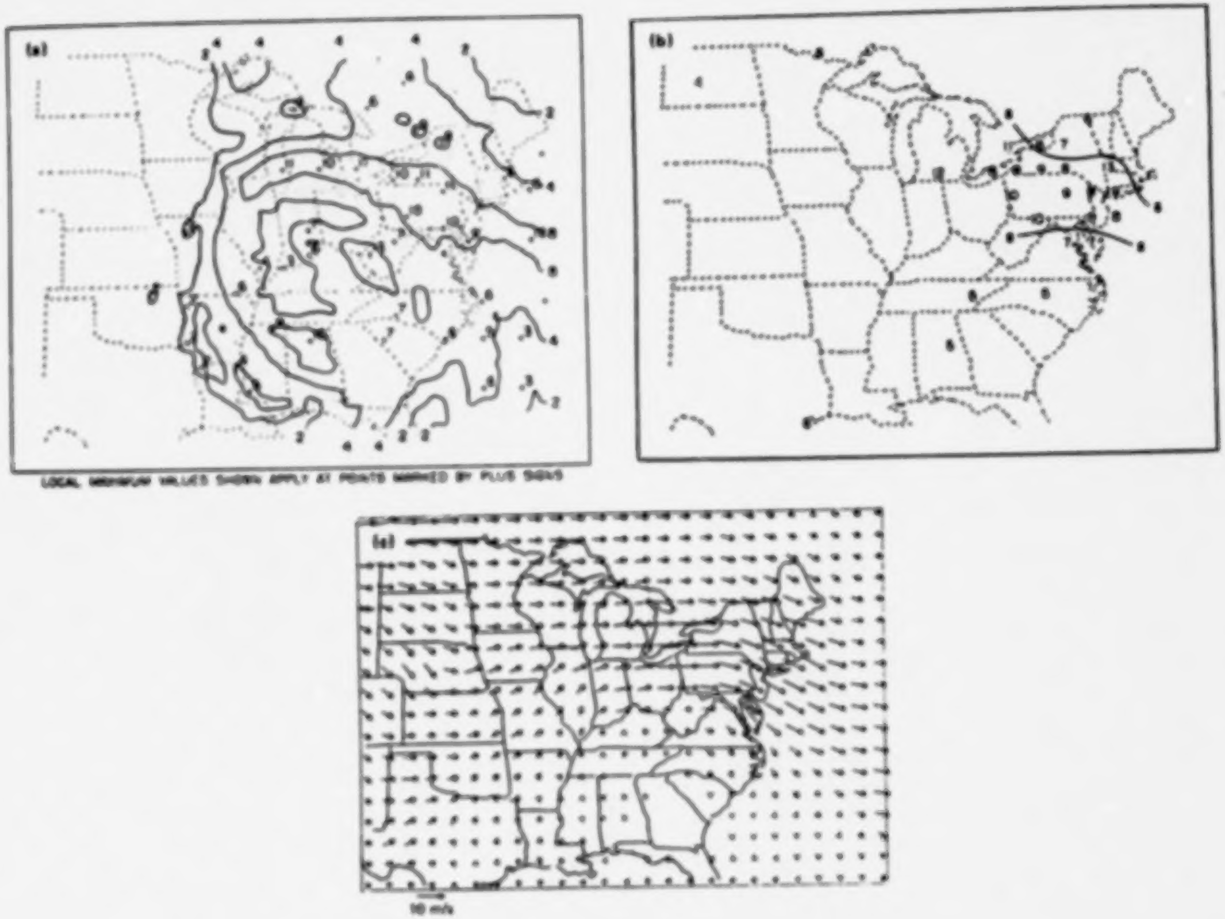

(a)
(b)
(c)
LOCAL MINIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS
10 m/s

Figure 6. $SO_4^=$ concentrations ($\mu g/m^3$) for January 1975.
(a) calculated, (b) measured, (c) mean monthly transport winds.

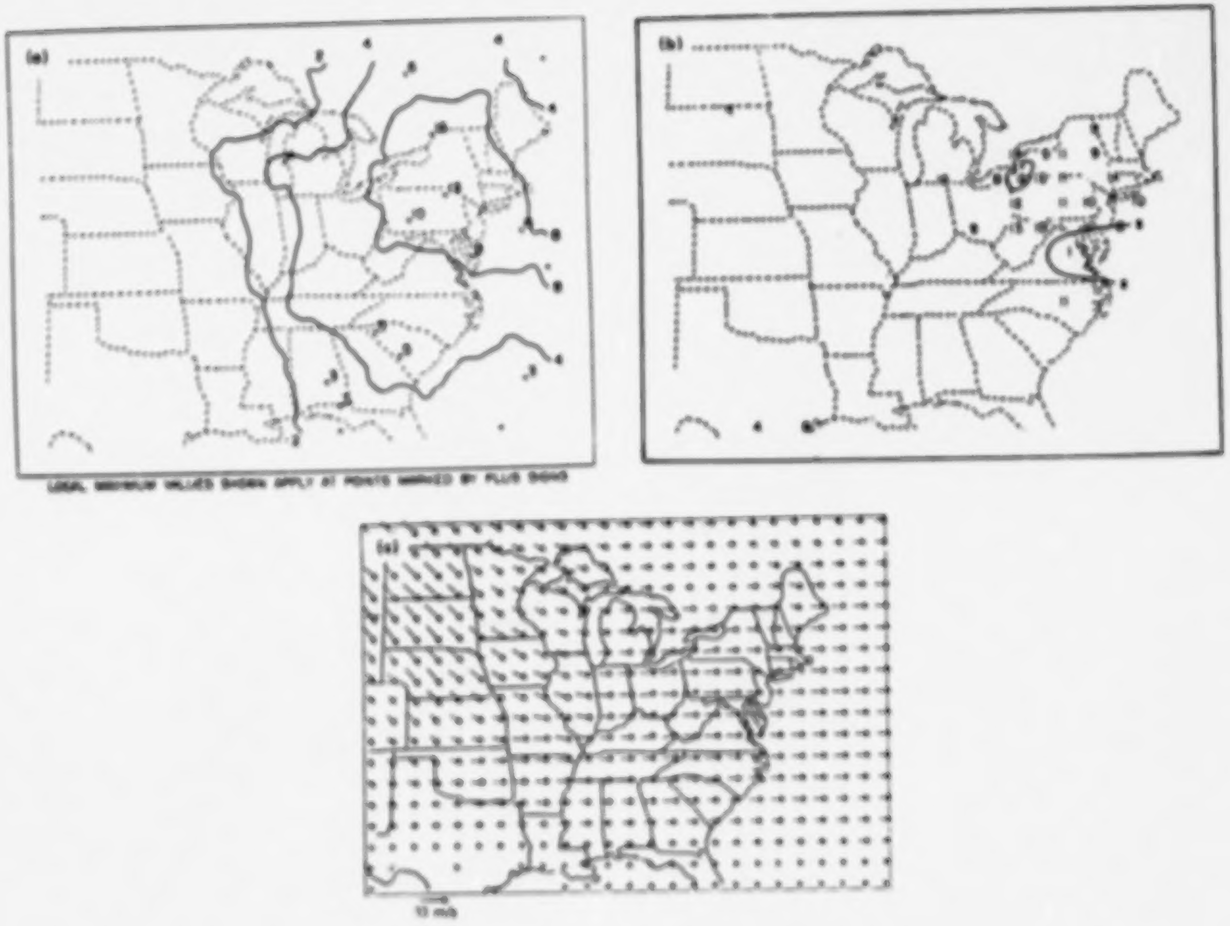
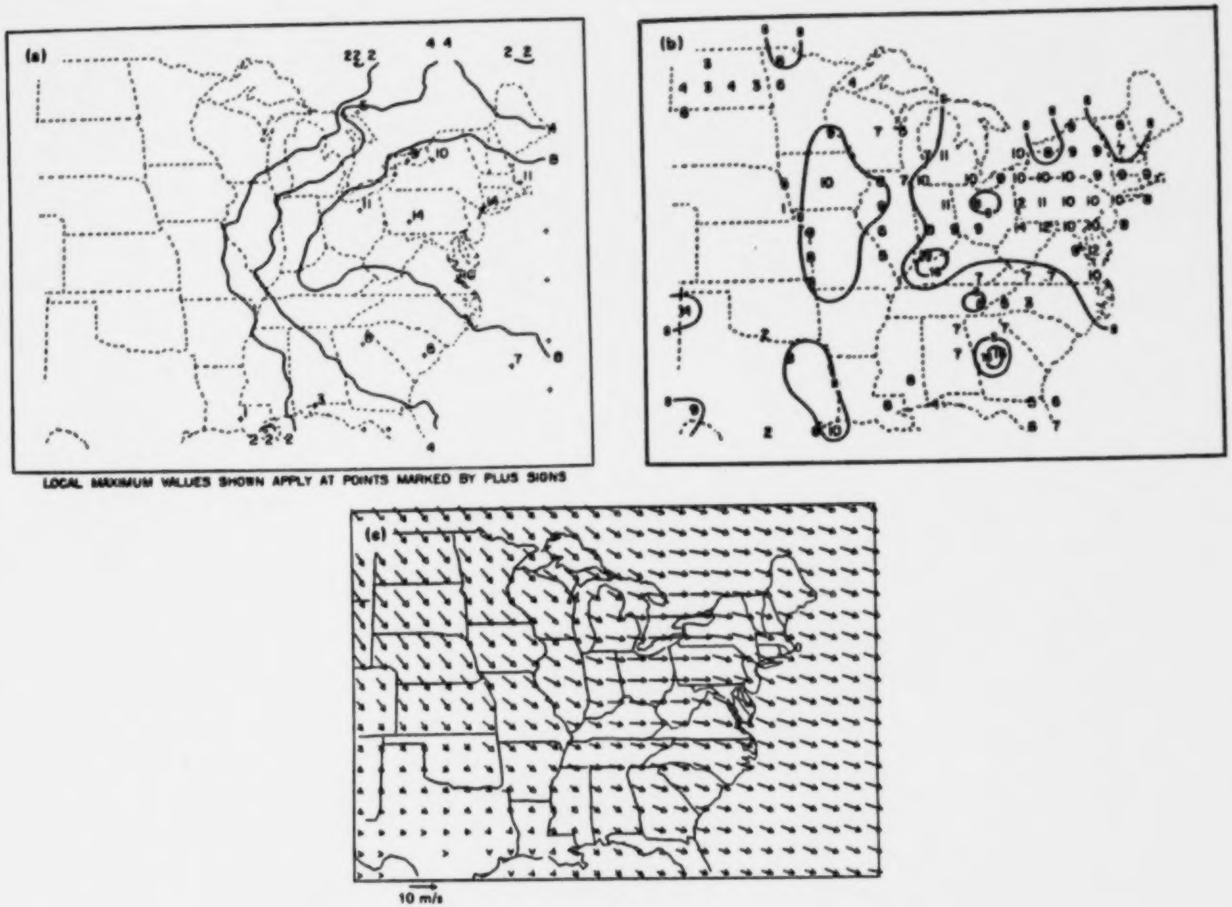

(a)
LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS
(b)
(c)
10 m/s

Figure 7. $SO_4^=$ concentrations ($\mu g/m^3$) for January 1976.
(a) calculated, (b) measured, (c) mean monthly transport winds.



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

Figure 8. $SO_4^=$ concentrations ($\mu g/m^3$) for January 1977.
(a) calculated, (b) measured, (c) mean monthly transport winds.

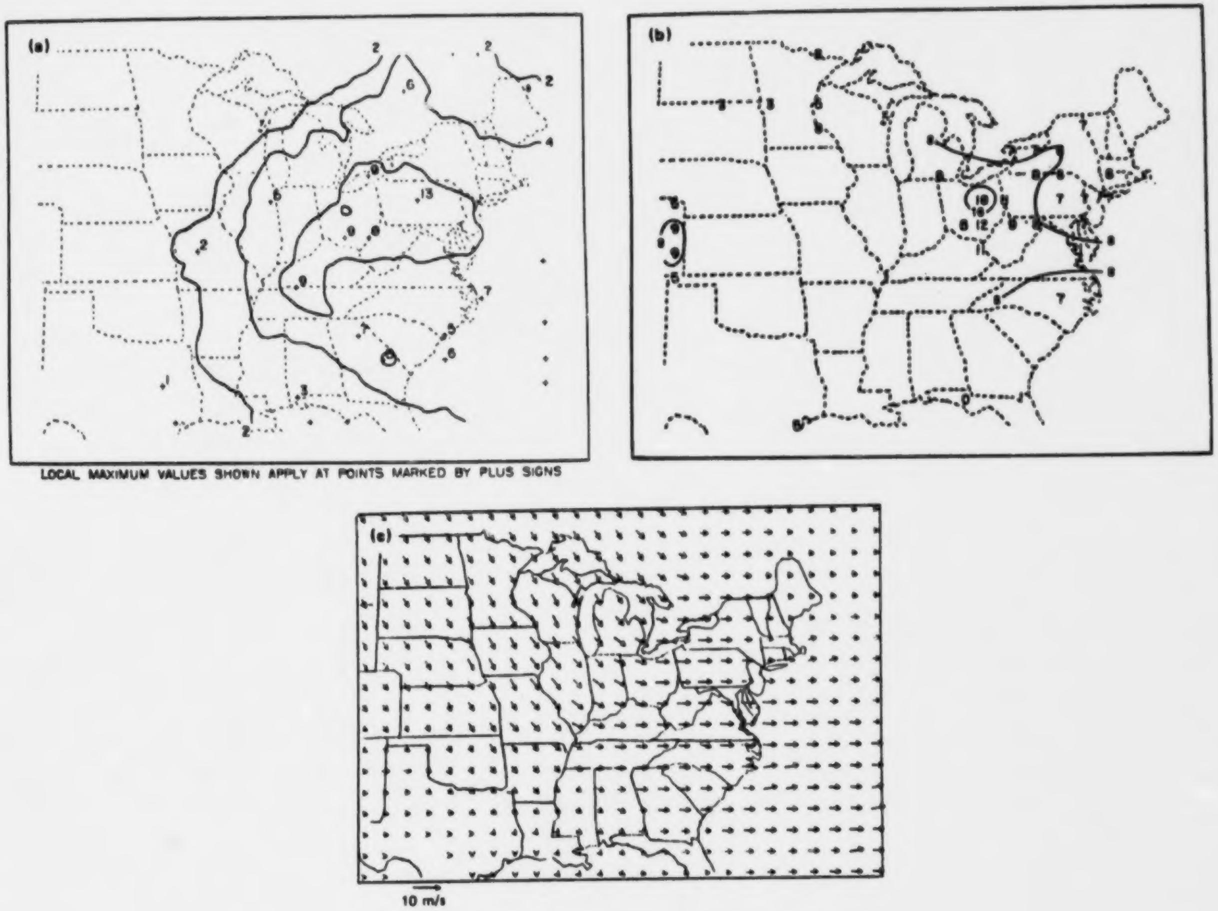

(a)
(b)
(c)
LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS
10 m/s

Figure 9. $SO_4^=$ concentrations ($\mu g/m^3$) for January 1978.
(a) calculated, (b) measured, (c) mean monthly transport winds.

relatively low values in the southeastern and northeastern United States, in agreement with the calculated results. A few measured values in the western part of the domain are relatively high and inconsistent with the calculated values; however, these measurements are probably associated with local sources.

*January 1976*—The calculated $SO_4^=$ concentration pattern for this period [Figure 7(a)] shows a center of high values ( $> 8$ $\mu g/m^3$) over the northeastern United States, while west of the Mississippi, the concentrations become quite low ( $< 2$ $\mu g/m^3$). The high values in the northeast of the United States indicate that there was a transport of the pollutant into this area, although this is not distinctly shown by the mean wind pattern of Figure 7(c). The calculated $SO_4^=$ concentrations for January 1976 [Figure 7(a)] and 1975 [Figure 6(a)] show definite differences. The $SO_4^=$ concentrations in New England were relatively low in January 1975, apparently because of stronger transport winds over this area. Also, the January 1976 pattern does not show as much variability in $SO_4^=$ concentrations as were produced in the Southeast during January 1975 in association with the anticyclonic circulation.

The $SO_4^=$ monitoring sites in January 1976 were again sparse. The available data [Figure 7(b)] appear to be generally consistent with the calculated concentrations. A large value (15 $\mu g/m^3$) in southern Michigan and a large value (11 $\mu g/m^3$) in North Carolina are inconsistent with the calculated results.

*January 1977*—The calculated $SO_4^=$ concentrations for January 1977 [Figure 8(a)] show that the higher $SO_4^=$ concentrations ( $> 8$ $\mu g/m^3$) are centered over the northeastern United States as in 1976; however the "8" isoline extends farther west, apparently because of differences in the transporting winds that are not evident from the monthly mean fields. The high $SO_4^=$ concentrations off the East Coast in 1975, 1976, and 1977 are a reflection of a prevailing wind blowing from northwest to southeast.

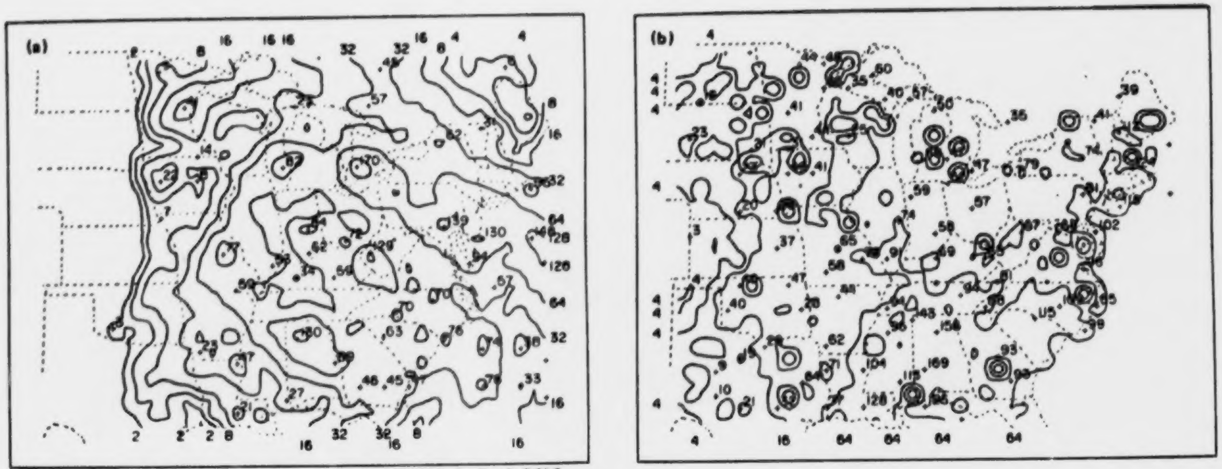
The number of available measured $SO_4^=$ concentrations for January 1977 [Figure 8(b)] provide a more desirable coverage. The measured data show high values in the northeastern United States that are consistent with the calculated values (based on 1977 emission data). However, some high measured values (up to 10 $\mu g/m^3$) that have been recorded west of the Mississippi are probably unrepresentative data.

*January 1978*—The calculated $SO_4^=$ concentration pattern for January 1978 [Figure 9(a)] is very similar to that for January 1977 [Figure 8(a)]. However, the 8–$\mu g/m^3$ isoline does not extend off the coast into the Atlantic apparently because the wind did not blow sulfur pollution off the coast as frequently during this January period as it did in 1977. The available measured data for this period [Figure 8(b)], which are again quite spotty, appear to be reasonably consistent with the calculations, with the exception of some high values, such as in Colorado.

### $SO_4^=$ Wet Depositions

The calculated $SO_4^=$ wet-depositions (mg/m$^2$) for January of each of the four years 1975, 1976, 1977, and 1978 are shown in Figures 10 through 13, along with the total monthly precipitation amounts. (The calculated $SO_2$ wet-deposition fields for the January months are shown in Appendix A.)

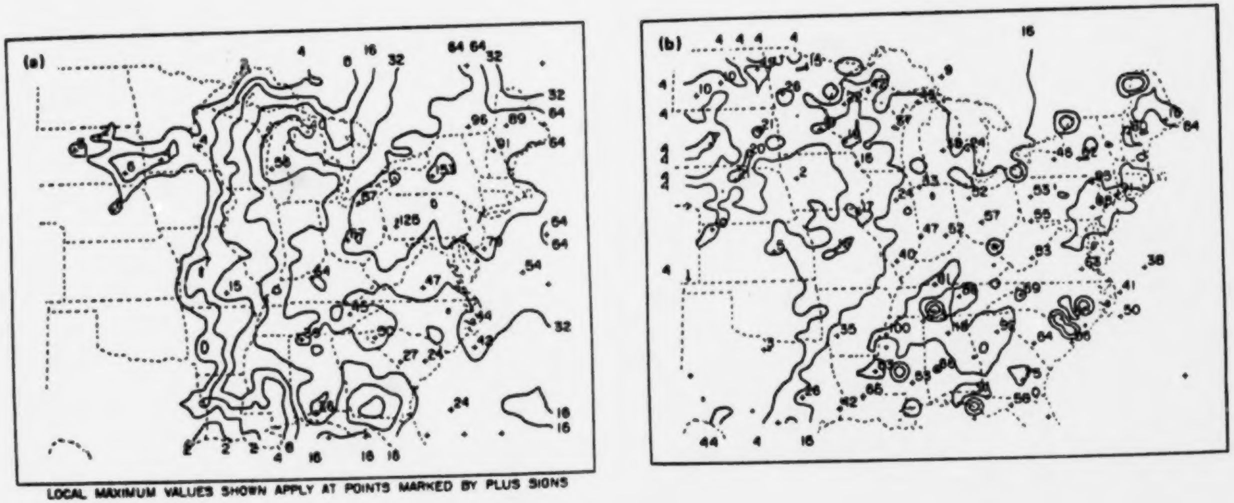
*January 1975*—During this winter month, high monthly precipitation amounts ( $> 64$ mm) occurred in the Southeast and along the East Coast, while small amounts ( $< 16$ mm) occurred in the far west of the domain [Figure 10(b)]. The small "no-rain" holes in the figures are



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

Figure 10. $SO_4^=$ wet depositions for January 1975.

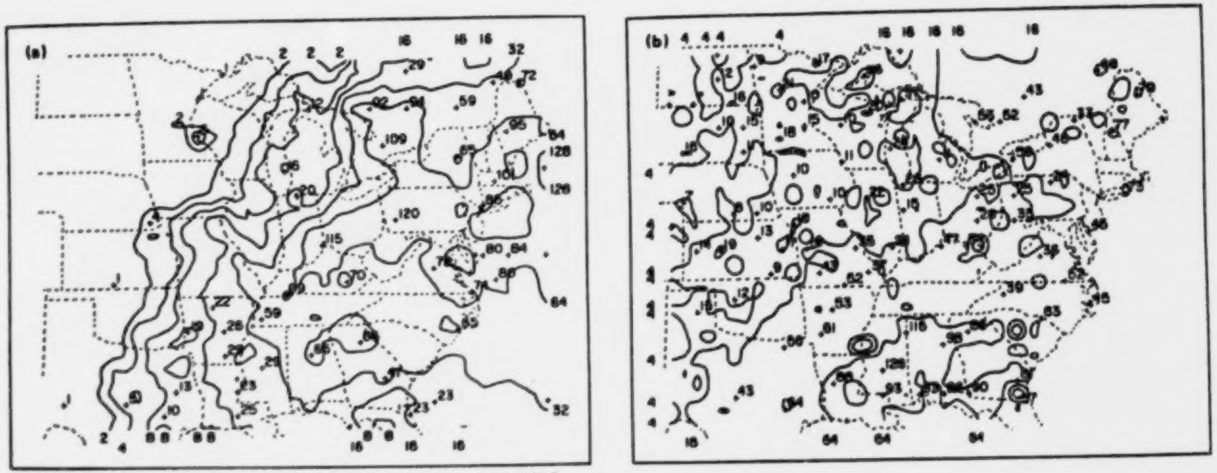
(a) calculated $SO_4^=$ wet depositions (mg/m$^2$), (b) precipitation (mm/month).



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

Figure 11. $SO_4^=$ wet depositions for January 1976.

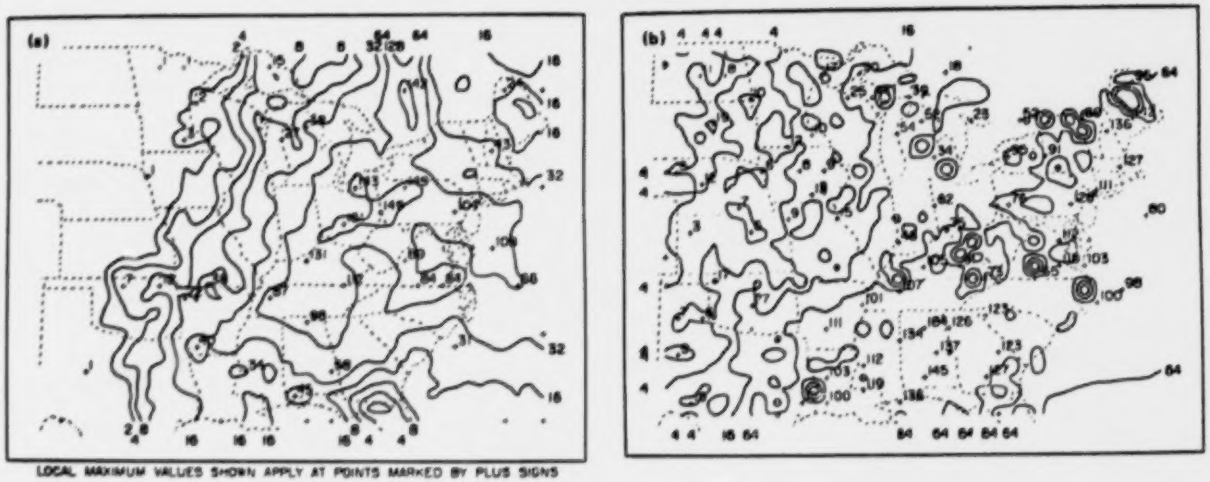
(a) calculated $SO_4^=$ wet depositions (mg/m$^2$), (b) precipitation (mm/month).



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

Figure 12. $SO_4^=$ wet depositions for January 1977.

(a) calculated $SO_4^=$ wet depositions ($mg/m^2$), (b) precipitation (mm/month).



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

Figure 13. $SO_4^=$ wet depositions for January 1978.

(a) calculated $SO_4^=$ wet depositions ($mg/m^2$), (b) precipitation (mm/month).

probably not real and are produced by missing rain reports that are recorded as no rain. However, in the long-term ENAMAP-1 model calculations, the effects of precipitation tend to be smoothed out. The $SO_4^=$ wet-deposition pattern [Figure 10(a)] is not very different from the $SO_4^=$ concentration pattern for January 1975 [Figure 6(a)]. However, it does show more spottiness and a greater irregularity along the strip of high values that crosses the northeast United States.

The high precipitation amounts along the East Coast appear to be reflected in the $SO_4^=$ wet depositions. However, the high precipitation amounts in the Southeast seem not to be. This could be caused either by the rain of the South being an infrequent, intense rainfall that does not deplete significantly more sulfur from the atmosphere than does frequent lighter rains, or by its occurrence at times of low $SO_4^=$ concentrations.

*January 1976*—During this winter month, areas with high monthly precipitation amounts ( > 64 mm) occurred in the Southeast and along the New England coast, while east of the Mississippi there was generally little rain ( < 16 mm). In this case, the high-rain area in the Southeast does seem to have affected the $SO_4^=$ wet-deposition pattern [Figure 11(a)], causing the tongue of high values to extend down into Alabama. The overall amount of rain for January 1976 was significantly less than that for January 1975. This appears to have resulted in overall lower calculated amounts of $SO_4^=$ wet deposition for January 1976 [Figure 11(a)] compared with those of January 1975 [Figure 10(a)].

*January 1977*—During this winter month, an area of high precipitation ( > 64 mm) occurred in the southeast United States over the Gulf Coast states, and there was relatively little rain ( < 16 mm) in the northwest part of the domain [Figure 12(b)]. The effects of these precipitation amounts are readily apparent in the $SO_4^=$ wet-deposition pattern for this month [Figure 12(a)]. For example, the $SO_4^=$ wet depositions for January 1977 show some high values in the southeast United States that do not show up in the $SO_4^=$ concentration pattern [Figure 8(a)] but that do correspond with high precipitation areas.

*January 1978*—During this winter month, there was extensive precipitation ( > 64 mm) over the entire Southeast and East Coast, and light amounts ( < 16 mm) in the west and (particularly) the northwest section of the domain [Figure 13(b)]. Again, this precipitation pattern is strongly reflected in the $SO_4^=$ wet-deposition pattern [Figure 13(a)].

### Interregional Exchanges

Table 2(a) through (d) shows the sulfur[*] exchanges between the regions of Figure 1 for January 1975, 1976, 1977, and 1978. The numerals 1 through 13 at the left of columns and the top of rows in the matrix of this table (as well as all other similar tables in the report) should not be confused with EPA/Canadian regions: These numbers have been assigned here merely to facilitate the interpretation of numbers included in the matrix in terms of emitter and receptor regions. An example of how to interpret these tables follows: Table 2(a) shows the sulfur deposition (wet and dry) and contribution percentages resulting from emissions from each of the 13 regions for January 1975. The values along the diagonal of the matrix represent the amounts of sulfur (in ktons) emitted by each region that is deposited within the region itself; for example, 59.7 ktons, or 60.5 percent, of the total sulfur deposited within the region designated by the numeral 2 (that is, Region V-North) came from its own emissions. Similarly, S. Ontario received from itself 74.2 ktons, or 48.9 percent, of the total sulfur deposition. The table also shows the amount received by each region from other emitter regions. For example, Region V-North received 23.2 ktons, or 23.5 percent, from Region V-South; 9.5 ktons, or 9.6 percent, from Region VII; and the remainder (6.4 percent) from the other regions.

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[*] The amount of sulfur (S) is given by $S = \frac{SO_2}{2} + \frac{SO_4^=}{3}$ .

Table 2(a) through (d) provides an indication of the year-by-year changes for the January month. For example, S. Quebec emitted 56.8 percent of the sulfur deposited within its area in January 1975, but only 36.8 percent in January 1976. This illustrates the importance of the yearly change in the prevailing winds and precipitation rates.

## Summary

The mean January wind pattern of 1975 was noticeably different from those of 1976, 1977, and 1978, which were very similar. Consequently, the mean measured $SO_2$ and $SO_4^=$ concentration patterns for January were similar for every year but the January of 1975. In particular, the $SO_4^=$ concentration field for January 1975 was noticeably different from those for the other three years: it exhibited considerable spatial variation throughout the southeastern United States, produced by the weak anticyclonic circulation that tended to persist over this region during January 1975.

The calculated and measured $SO_2$ concentrations appear to show a closer agreement during the January 1976 and 1977 periods. This is probably caused by the use of only one emission inventory, which is most representative of the January 1976 and 1977 periods. Differences between calculated and measured $SO_2$ concentrations are also attributable to:

- Measured data that were obtained close to a local source and therefore were unrepresentative of large-scale area average values.
- Natural sulfur background that was not included in calculated results.
- No consideration of emission sources that were outside the domain.

The calculated and measured $SO_4^=$ concentrations appear to be in reasonable agreement during all the January periods; however the measured $SO_4^=$ concentration data generally are not very complete.

The January monthly precipitation *amounts* for all four years generally showed relatively high values in the Southeast and along the East Coast and low values in the west of the domain. There were, however, considerable changes in the January precipitation *patterns* from year to year, which were generally reflected in the $SO_4^=$ wet-deposition patterns.

## TABLE 2 CALCULATED INTERREGIONAL EXCHANGES OF SULFUR FOR JANUARY 1975, 1976, 1977, 1978*

### (a) JANUARY 1975

TOTAL CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS (kilotons)

| EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 VIII-NORTH | .7 | .2 | .0 | .1 | 0.0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 2 V-NORTH | .1 | 59.7 | 31.0 | .9 | 0.0 | .0 | 11.2 | .1 | .3 | 10.1 | 5.4 | 1.2 | 1.7 |
| 3 S ONTARIO | .0 | 2.2 | 74.2 | 0.0 | 0.0 | 0.0 | 1.3 | 0.0 | .1 | 7.2 | 12.0 | 4.0 | 4.7 |
| 4 VII | .0 | 9.5 | 2.5 | 30.4 | .0 | 1.4 | 12.6 | 1.3 | 2.7 | .8 | .8 | .2 | .1 |
| 5 VIII-SOUTH | 0.0 | 0.0 | 0.0 | .0 | .0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 VI-EAST | .0 | .8 | .4 | 3.9 | .0 | 34.4 | .7 | 3.1 | .4 | .1 | .2 | .0 | .0 |
| 7 V-SOUTH | .0 | 23.2 | 17.3 | 6.9 | 0.0 | .3 | 140.8 | 4.8 | 29.5 | 51.7 | 4.5 | 1.0 | 1.9 |
| 8 IV-SOUTH | 0.0 | .4 | .7 | 1.5 | 0.0 | 5.0 | 2.2 | 87.0 | 20.4 | 1.5 | .3 | .1 | .1 |
| 9 IV-NORTH | .0 | 2.7 | 3.1 | 4.8 | 0.0 | 1.6 | 27.8 | 10.8 | 79.7 | 10.4 | 1.0 | .3 | .4 |
| 10 III | 0.0 | .0 | 10.0 | .0 | 0.0 | .1 | 10.8 | 3.1 | 15.0 | 110.6 | 10.5 | 1.2 | 2.4 |
| 11 II | 0.0 | 0.0 | 4.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .0 | 2.6 | 17.0 | 3.1 | 1.4 |
| 12 I | 0.0 | 0.0 | .0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .0 | .7 | 10.6 | 16.8 | 2.1 |
| 13 S QUEBEC | 0.0 | 0.0 | 8.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .0 | .4 | 5.2 | 19.5 |
| TOTAL (KTON S) | .8 | 98.7 | 151.8 | 48.6 | .0 | 42.9 | 207.5 | 110.1 | 148.0 | 195.8 | 62.7 | 32.8 | 34.3 |

PERCENT CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS

| EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 VIII-NORTH | 84.6 | .2 | .0 | .2 | 0.0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 2 V-NORTH | 9.5 | 60.5 | 20.4 | 1.9 | 0.0 | .0 | 5.4 | .1 | .2 | 5.2 | 8.6 | 3.6 | 4.9 |
| 3 S ONTARIO | .0 | 2.2 | 48.9 | 0.0 | 0.0 | 0.0 | .6 | 0.0 | .0 | 3.7 | 19.1 | 12.0 | 13.7 |
| 4 VII | 3.7 | 9.6 | 1.6 | 62.5 | .0 | 3.3 | 6.1 | 1.2 | 1.8 | .4 | 1.3 | .5 | .4 |
| 5 VIII-SOUTH | 0.0 | 0.0 | 0.0 | .0 | 93.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 VI-EAST | 1.7 | .9 | .3 | 8.0 | 6.2 | 80.0 | .3 | 2.8 | .2 | .1 | .3 | .1 | .1 |
| 7 V-SOUTH | .5 | 23.5 | 11.4 | 14.3 | 0.0 | .8 | 67.9 | 4.4 | 19.9 | 26.4 | 7.2 | 2.9 | 5.5 |
| 8 IV-SOUTH | 0.0 | .4 | .5 | 3.2 | 0.0 | 11.7 | 1.1 | 79.0 | 13.8 | .7 | .5 | .2 | .3 |
| 9 IV-NORTH | .0 | 2.8 | 2.1 | 10.0 | 0.0 | 3.8 | 13.4 | 9.8 | 53.9 | 5.3 | 1.6 | .8 | 1.3 |
| 10 III | 0.0 | .0 | 6.6 | .0 | 0.0 | .3 | 5.2 | 2.8 | 10.1 | 56.5 | 16.8 | 3.6 | 7.1 |
| 11 II | 0.0 | 0.0 | 2.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .0 | 1.3 | 27.1 | 9.4 | 4.0 |
| 12 I | 0.0 | 0.0 | .0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .0 | .4 | 16.9 | 51.1 | 6.0 |
| 13 S QUEBEC | 0.0 | 0.0 | 5.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .0 | .7 | 15.8 | 56.8 |

## TABLE 2 (continued)

### (b) JANUARY 1976

TOTAL CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS (kilotons)

| EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 VIII-NORTH | .6 | .1 | .0 | .2 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 2 V-NORTH | .7 | 58.3 | 25.5 | 3.1 | 0.0 | .1 | 18.1 | .6 | 1.9 | 7.4 | 4.5 | 1.8 | 3.6 |
| 3 S. ONTARIO | .0 | 4.7 | 70.6 | .0 | 0.0 | 0.0 | 3.1 | .0 | .5 | 6.5 | 10.1 | 3.5 | 11.2 |
| 4 VII | .2 | 4.7 | 2.2 | 24.8 | .0 | 2.4 | 13.1 | 3.0 | 5.7 | 1.3 | .6 | .3 | .7 |
| 5 VIII-SOUTH | 0.0 | 0.0 | 0.0 | .0 | .0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 VI-EAST | 0.0 | .2 | .2 | 1.8 | 0.0 | 24.0 | 1.3 | 4.9 | 2.0 | .6 | .1 | .1 | .1 |
| 7 V-SOUTH | .0 | 14.7 | 22.1 | 6.8 | 0.0 | .1 | 125.0 | 6.0 | 35.7 | 45.2 | 10.8 | 3.6 | 6.8 |
| 8 IV-SOUTH | 0.0 | .0 | .2 | .0 | 0.0 | .8 | 1.6 | 63.6 | 24.4 | 5.0 | .8 | .2 | .1 |
| 9 IV-NORTH | 0.0 | .3 | 4.2 | .1 | 0.0 | .3 | 18.3 | 9.8 | 72.6 | 17.3 | 3.4 | 1.3 | 1.5 |
| 10 III | 0.0 | .0 | 5.5 | 0.0 | 0.0 | 0.0 | 12.8 | .3 | 8.8 | 112.3 | 20.3 | 6.5 | 5.8 |
| 11 II | 0.0 | 0.0 | 4.1 | 0.0 | 0.0 | 0.0 | .1 | .0 | .0 | 2.4 | 19.3 | 6.1 | 2.4 |
| 12 I | 0.0 | 0.0 | .1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .0 | .1 | 11.9 | 22.3 | 2.8 |
| 13 S. QUEBEC | 0.0 | .0 | 8.3 | 0.0 | 0.0 | 0.0 | .0 | 0.0 | .0 | .2 | 1.0 | 4.5 | 20.4 |
| TOTAL (KTON S) | 1.5 | 83.0 | 142.8 | 36.9 | .0 | 27.8 | 193.5 | 88.2 | 151.5 | 198.1 | 82.8 | 50.1 | 55.5 |

PERCENT CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS

| EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 VIII-NORTH | 38.8 | .1 | .0 | .5 | 7.1 | .1 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 2 V-NORTH | 45.8 | 70.2 | 17.8 | 8.5 | 0.0 | .3 | 9.4 | .7 | 1.3 | 3.7 | 5.4 | 3.5 | 6.6 |
| 3 S. ONTARIO | .0 | 5.7 | 49.4 | .0 | 0.0 | 0.0 | 1.6 | .1 | .3 | 3.3 | 12.2 | 6.9 | 20.1 |
| 4 VII | 15.0 | 5.6 | 1.5 | 67.3 | .0 | 8.6 | 6.8 | 3.4 | 3.8 | .7 | .8 | .7 | 1.2 |
| 5 VIII-SOUTH | 0.0 | 0.0 | 0.0 | .0 | 92.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 VI-EAST | 0.0 | .3 | .1 | 4.8 | 0.0 | 86.2 | .7 | 5.5 | 1.3 | .3 | .2 | .1 | .2 |
| 7 V-SOUTH | .4 | 17.8 | 15.5 | 18.4 | 0.0 | .5 | 64.6 | 6.8 | 23.5 | 22.8 | 13.0 | 7.1 | 12.3 |
| 8 IV-SOUTH | 0.0 | .0 | .2 | .1 | 0.0 | 3.0 | .8 | 72.1 | 16.1 | 2.5 | 1.0 | .4 | .2 |
| 9 IV-NORTH | 0.0 | .3 | 2.9 | .4 | 0.0 | 1.2 | 9.4 | 11.1 | 47.9 | 8.7 | 4.2 | 2.6 | 2.8 |
| 10 III | 0.0 | .0 | 3.8 | 0.0 | 0.0 | 0.0 | 6.6 | .4 | 5.8 | 56.7 | 24.5 | 13.0 | 10.5 |
| 11 II | 0.0 | 0.0 | 2.9 | 0.0 | 0.0 | 0.0 | .0 | .0 | .0 | 1.2 | 23.3 | 12.3 | 4.3 |
| 12 I | 0.0 | 0.0 | .1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .0 | .0 | 14.4 | 44.4 | 5.0 |
| 13 S. QUEBEC | 0.0 | .0 | 5.8 | 0.0 | 0.0 | 0.0 | .0 | 0.0 | .0 | .1 | 1.2 | 9.0 | 36.8 |

TABLE 2 (continued)

(c) JANUARY 1977

TOTAL CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS (kilotons)

| | EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | VIII-NORTH | .8 | .1 | .0 | .2 | .0 | .1 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 2 | V-NORTH | .0 | 46.9 | 26.4 | 3.8 | 0.0 | .1 | 21.5 | .4 | 1.6 | 9.8 | 6.4 | 2.4 | 2.0 |
| 3 | S. ONTARIO | .0 | 3.3 | 71.6 | 0.0 | 0.0 | 0.0 | 3.0 | 0.0 | .1 | 6.8 | 12.5 | 5.7 | 8.0 |
| 4 | VII | .0 | 1.4 | .5 | 29.5 | .0 | 3.5 | 10.8 | 4.0 | 7.6 | 1.5 | .3 | .3 | .2 |
| 5 | VIII-SOUTH | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 | VI-EAST | .0 | .0 | .0 | 1.1 | .0 | 29.9 | .1 | 3.8 | .3 | .0 | .0 | .0 | .0 |
| 7 | V-SOUTH | 0.0 | 5.2 | 8.1 | 8.6 | 0.0 | .3 | 122.0 | 5.8 | 42.4 | 54.7 | 8.1 | 3.8 | 2.3 |
| 8 | IV-SOUTH | 0.0 | 0.0 | 0.0 | .0 | 0.0 | 2.2 | .3 | 72.2 | 17.3 | .8 | .0 | .0 | 0.0 |
| 9 | IV-NORTH | 0.0 | .0 | .4 | .2 | 0.0 | .7 | 12.8 | 11.9 | 80.0 | 14.1 | 1.1 | .7 | .3 |
| 10 | III | 0.0 | .1 | 1.8 | 0.0 | 0.0 | 0.0 | 12.2 | .0 | 8.3 | 106.1 | 13.2 | 5.4 | 1.0 |
| 11 | II | 0.0 | .0 | 3.8 | 0.0 | 0.0 | 0.0 | .0 | 0.0 | 0.0 | 1.8 | 15.6 | 5.3 | .8 |
| 12 | I | 0.0 | 0.0 | .1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .3 | 8.4 | 18.6 | 2.0 |
| 13 | S. QUEBEC | 0.0 | .2 | 7.2 | 0.0 | 0.0 | 0.0 | .0 | 0.0 | 0.0 | .0 | .6 | 6.0 | 22.9 |
| | TOTAL (KTON S) | .8 | 57.3 | 120.0 | 43.4 | .0 | 36.8 | 182.9 | 98.2 | 157.5 | 196.0 | 66.1 | 48.0 | 39.4 |

PERCENT CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS

| | EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | VIII-NORTH | 95.8 | .1 | .0 | .5 | 17.8 | .1 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 2 | V-NORTH | 3.1 | 82.0 | 22.0 | 8.8 | 0.0 | .3 | 11.8 | .4 | 1.0 | 5.0 | 9.7 | 5.0 | 4.9 |
| 3 | S. ONTARIO | .0 | 5.8 | 59.7 | 0.0 | 0.0 | 0.0 | 1.6 | 0.0 | .0 | 3.5 | 18.9 | 11.8 | 20.4 |
| 4 | VII | 1.1 | 2.5 | .4 | 67.9 | .0 | 9.4 | 5.9 | 4.1 | 4.8 | .8 | .4 | .6 | .5 |
| 5 | VIII-SOUTH | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 | VI-EAST | .0 | .0 | .0 | 2.5 | 82.2 | 81.3 | .1 | 3.9 | .2 | .0 | .0 | .0 | .0 |
| 7 | V-SOUTH | 0.0 | 9.2 | 6.8 | 19.8 | 0.0 | .9 | 66.7 | 5.9 | 26.9 | 27.9 | 12.2 | 7.8 | 5.8 |
| 8 | IV-SOUTH | 0.0 | 0.0 | 0.0 | .0 | 0.0 | 6.1 | .2 | 73.5 | 11.0 | .4 | .0 | .0 | 0.0 |
| 9 | IV-NORTH | 0.0 | .0 | .3 | .4 | 0.0 | 1.9 | 7.0 | 12.1 | 50.8 | 7.2 | 1.6 | 1.5 | .8 |
| 10 | III | 0.0 | .1 | 1.5 | 0.0 | 0.0 | 0.0 | 6.7 | .0 | 5.3 | 54.1 | 19.9 | 11.2 | 2.5 |
| 11 | II | 0.0 | .0 | 3.2 | 0.0 | 0.0 | 0.0 | .0 | 0.0 | 0.0 | .9 | 23.6 | 11.0 | 2.0 |
| 12 | I | 0.0 | 0.0 | .1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .1 | 12.7 | 38.7 | 5.0 |
| 13 | S. QUEBEC | 0.0 | .3 | 6.0 | 0.0 | 0.0 | 0.0 | .0 | 0.0 | 0.0 | .0 | .9 | 12.5 | 58.0 |

## TABLE 2 (concluded)

### (d) JANUARY 1978

TOTAL CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS (kilotons)

| EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 VIII-NORTH | .7 | .1 | .0 | .1 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 2 V-NORTH | .1 | 54.6 | 16.9 | 7.5 | 0.0 | 1.4 | 27.2 | 1.3 | 3.4 | 7.7 | 3.5 | 1.4 | 1.4 |
| 3 S. ONTARIO | .0 | 10.5 | 69.9 | .2 | 0.0 | .3 | 8.2 | 1.0 | 1.7 | 5.3 | 9.6 | 4.6 | 4.8 |
| 4 VII | .0 | 2.0 | 1.0 | 28.9 | .0 | 7.2 | 9.4 | 4.5 | 5.6 | .5 | .2 | .1 | .4 |
| 5 VIII-SOUTH | 0.0 | 0.0 | 0.0 | .0 | .0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 VI-EAST | 0.0 | .1 | .1 | 1.2 | .0 | 29.5 | .4 | 2.8 | .9 | .1 | .0 | .0 | .0 |
| 7 V-SOUTH | 0.0 | 7.5 | 11.7 | 10.2 | 0.0 | 4.0 | 138.7 | 7.6 | 45.1 | 40.8 | 4.8 | 1.6 | 2.5 |
| 8 IV-SOUTH | 0.0 | .0 | .4 | .0 | 0.0 | 1.5 | .7 | 75.3 | 21.1 | 2.1 | .1 | .0 | .1 |
| 9 IV-NORTH | 0.0 | .1 | 2.5 | .1 | 0.0 | .8 | 17.7 | 10.9 | 85.9 | 11.6 | .7 | .2 | .5 |
| 10 III | 0.0 | .0 | 5.2 | .0 | 0.0 | .0 | 19.3 | .2 | 10.3 | 115.5 | 11.7 | 2.6 | 2.0 |
| 11 II | 0.0 | .0 | 6.5 | .0 | 0.0 | .0 | .3 | .0 | .1 | 4.5 | 18.3 | 4.4 | 1.1 |
| 12 I | 0.0 | 0.0 | .4 | 0.0 | 0.0 | 0.0 | .0 | .0 | .0 | 1.8 | 13.9 | 21.3 | 2.2 |
| 13 S. QUEBEC | 0.0 | .8 | 11.0 | .1 | 0.0 | .0 | .4 | .0 | .1 | .3 | 1.6 | 4.3 | 18.2 |
| TOTAL (KTON S) | .8 | 76.0 | 125.6 | 48.3 | .0 | 44.9 | 223.0 | 103.7 | 174.4 | 190.3 | 64.5 | 40.4 | 33.2 |

PERCENT CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS

| EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 VIII-NORTH | 84.5 | .1 | .0 | .3 | 32.3 | .1 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 2 V-NORTH | 13.1 | 72.1 | 13.4 | 15.5 | 0.0 | 3.1 | 12.2 | 1.3 | 2.0 | 4.0 | 5.5 | 3.4 | 4.3 |
| 3 S. ONTARIO | .0 | 13.8 | 55.6 | .4 | 0.0 | .6 | 3.7 | .9 | 1.0 | 2.8 | 14.8 | 11.3 | 14.4 |
| 4 VII | 2.4 | 2.7 | .8 | 59.8 | .0 | 16.0 | 4.2 | 4.3 | 3.2 | .3 | .3 | .3 | 1.1 |
| 5 VIII-SOUTH | 0.0 | 0.0 | 0.0 | .0 | 14.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 VI-EAST | 0.0 | .1 | .1 | 2.4 | 53.0 | 65.8 | .2 | 2.7 | .5 | .0 | .0 | .0 | .1 |
| 7 V-SOUTH | 0.0 | 9.8 | 9.3 | 21.2 | 0.0 | 9.0 | 62.2 | 7.4 | 25.9 | 21.5 | 7.4 | 4.0 | 7.4 |
| 8 IV-SOUTH | 0.0 | .1 | .3 | .0 | 0.0 | 3.4 | .3 | 72.7 | 12.1 | 1.1 | .1 | .0 | .3 |
| 9 IV-NORTH | 0.0 | .2 | 2.0 | .2 | 0.0 | 1.8 | 7.9 | 10.5 | 49.3 | 6.1 | 1.1 | .5 | 1.6 |
| 10 III | 0.0 | .1 | 4.1 | .0 | 0.0 | .0 | 8.9 | .2 | 5.9 | 60.7 | 18.1 | 6.4 | 6.1 |
| 11 II | 0.0 | .0 | 5.2 | .0 | 0.0 | .0 | .2 | .0 | .1 | 2.4 | 28.4 | 10.8 | 3.4 |
| 12 I | 0.0 | 0.0 | .4 | 0.0 | 0.0 | 0.0 | .0 | .0 | .0 | 1.0 | 21.6 | 52.8 | 6.6 |
| 13 S. QUEBEC | 0.0 | 1.1 | 8.8 | .1 | 0.0 | .0 | .2 | .0 | .1 | .2 | 2.5 | 10.7 | 54.8 |

*All results are based on emission data for 1977. A value of 0.0 in the tables indicates no sulfur deposition occurred; a value of .0 signifies a sulfur deposition of less than 0.05 ktons.

# SECTION 5

# RESULTS FOR JULY (1975, 1976, 1978) AND AUGUST 1977

## $SO_2$ Concentrations

The calculated and measured $SO_2$ concentrations for the July months of the four years 1975, 1976, 1977, and 1978[*] are shown in Figures 14 through 17. Also shown in these figures are the monthly mean wind vector fields of the 3-hourly winds used for transporting the $SO_2$ puffs. Overall, the July winds are considerably lighter than those for the January months [part (c) of Figures 2 through 5]. Results for the calculated July $SO_2$ dry depositions, which are proportional to the $SO_2$ concentrations, are shown in Appendix A.

*July 1975*—The mean wind field for July 1975 [Figure 14(c)] shows a westerly flow in the north and an anticyclonic flow pattern of very light winds in the southeast United States. The calculated $SO_2$ concentration field [Figure 14(a)] shows maximum concentrations ( $\geqslant$ 64 μg/m$^3$) near Pittsburgh, and other high concentration centers ( > 32 μg/m$^3$) near the cities of Cincinnati, Cleveland, Detroit, Sudbury (Ontario), and in eastern Kentucky--generally corresponding with high emission areas. Relatively high calculated-concentration centers also appear near Atlanta and Mobile. These 1975 July $SO_2$-concentration patterns are similar to those given for the January months [e.g., Figure 2(c)], except that in the January months the higher $SO_2$-concentration isolines are extended more to the east because of the stronger westerly winds. The lighter summer winds would tend to produce relatively large model-calculated $SO_2$ concentrations in this July 1975 month, but this is offset by the use of a relatively high summer mixing height.

The measured values for the July 1975 $SO_2$ concentrations are shown in Figure 14(b). There were no measured values available for the Canadian regions during this July 1975 period for making comparisons with the model calculations. A comparison of the calculated and measured values shows that:

- The calculated results for July 1975 generally compare favorably with the measured values, in regard to both patterns and magnitudes. For example, the 32 μg/m$^3$ isoline for the measured value that is centered over Pittsburgh coincides with the 32 isoline for the calculated values; the four measured values above 40 are located within the 32 μg/m$^3$ isoline that encompasses the calculated values greater than 32.
- The highest calculated value in the domain is 78 μg/m$^3$, which closely coincides with a measured peak value of only 55. However, the calculated values apply to a 70- by 70-km grid, while the measured values apply to a 140- by 140-km grid. Thus, the measured value of 55 μg/m$^3$ should actually be compared with a calculated value averaged

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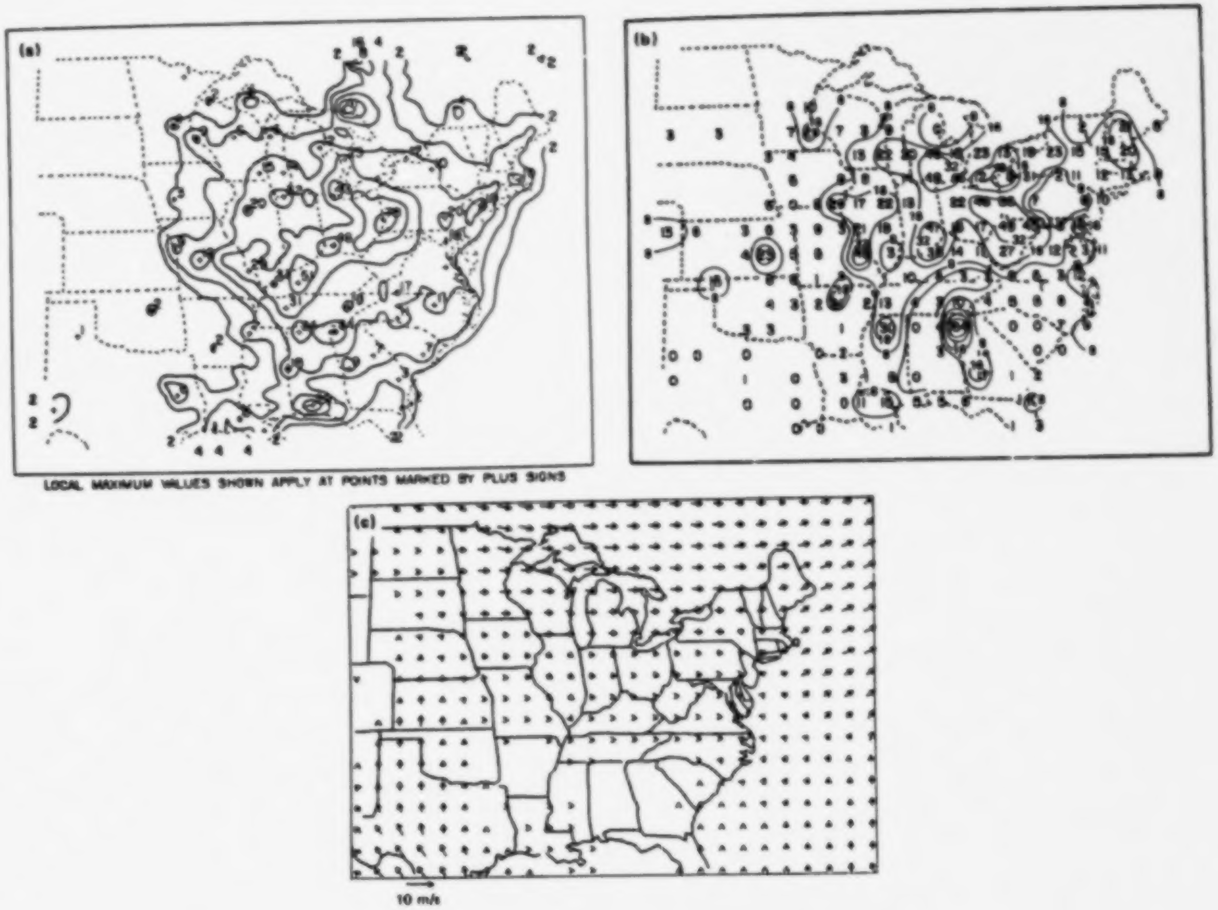
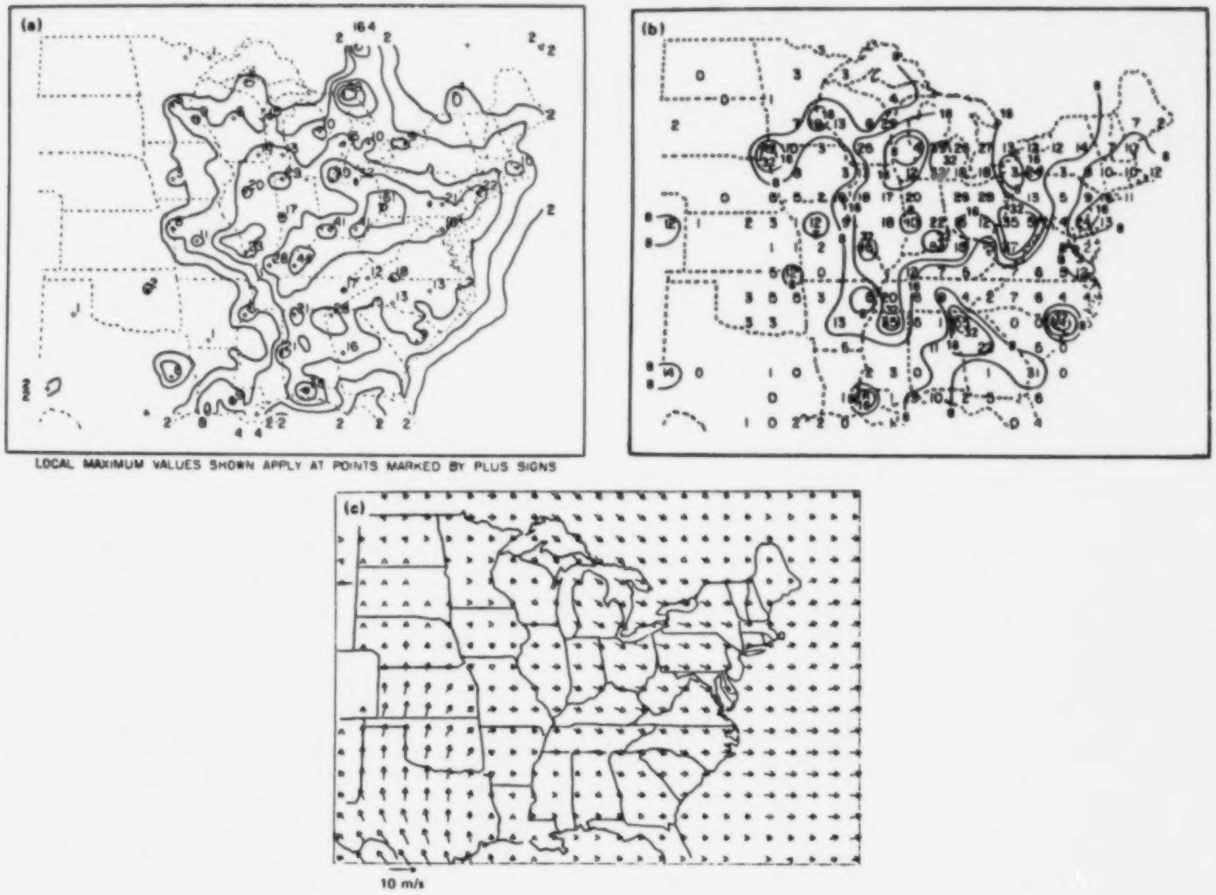
[*] August data were substituted for those of July for the year 1977.



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

Figure 14. $SO_2$ concentrations ($\mu g/m^3$) for July 1975.
(a) calculated, (b) measured, (c) mean monthly transport winds.



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

Figure 15. $SO_2$ concentrations ($\mu g/m^3$) for July 1976.
(a) calculated, (b) measured, (c) mean monthly transport winds.

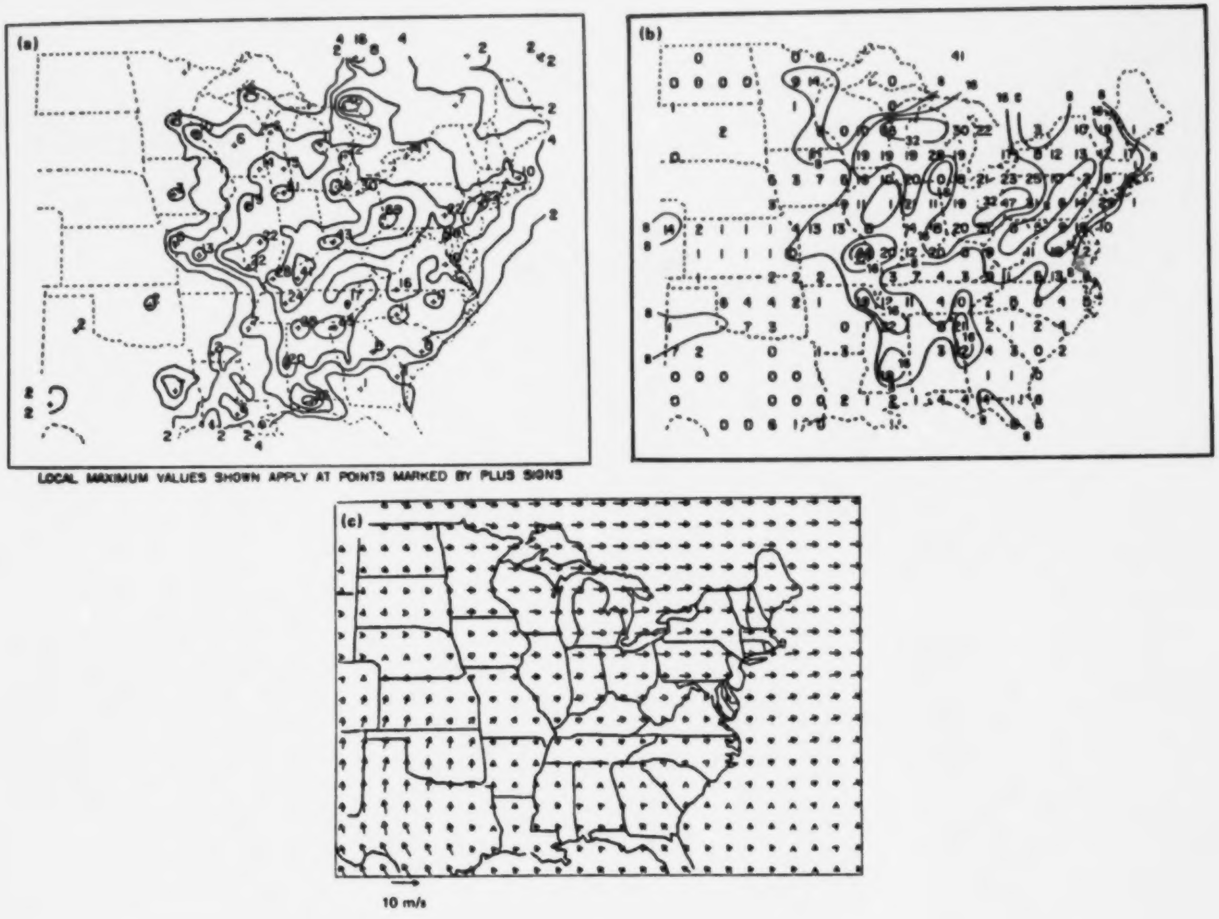
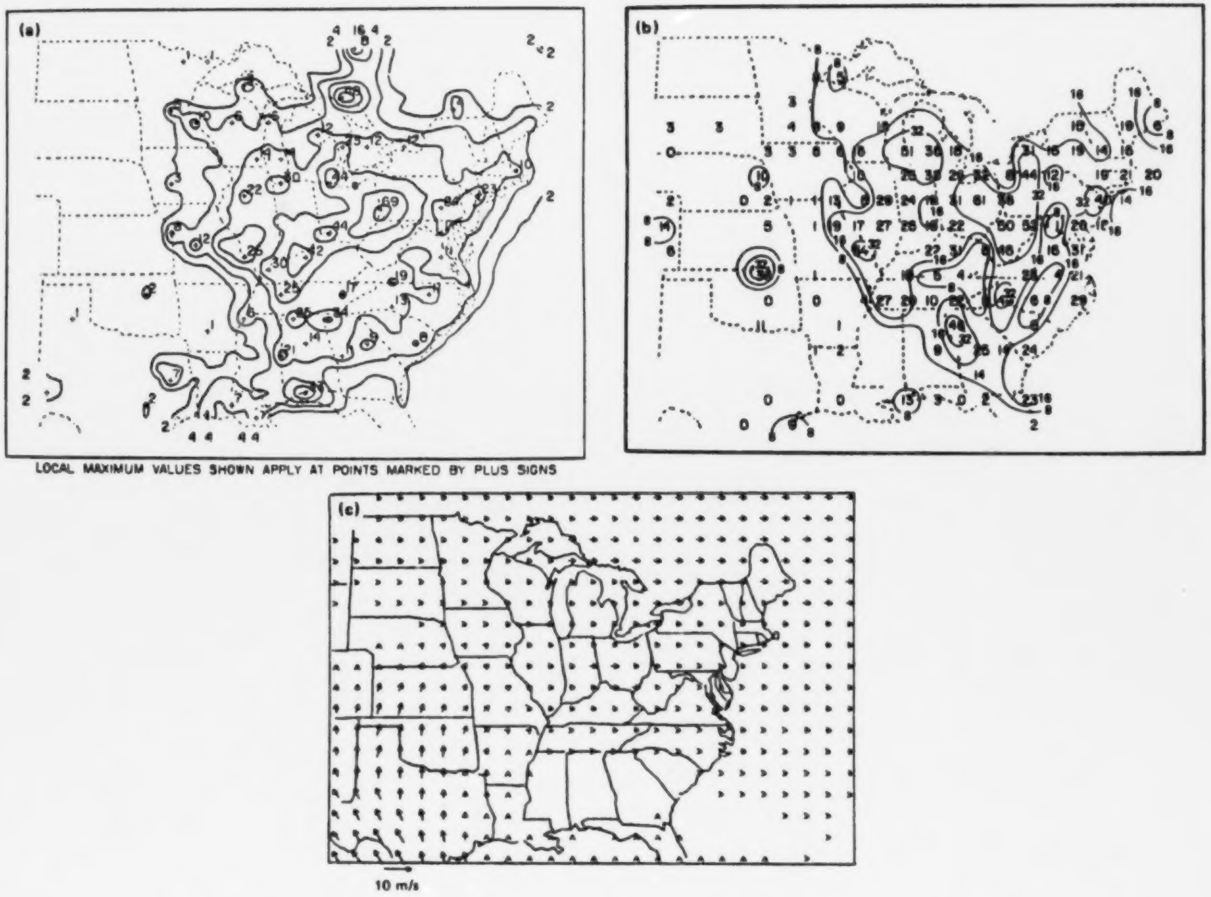

(a)
LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS
(b)
(c)
10 m/s

Figure 16. SO$_2$ concentrations ($\mu$g/m$^3$) for August 1977.
(a) calculated, (b) measured, (c) mean monthly transport winds.



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

Figure 17. $SO_2$ concentrations ($\mu g/m^3$) for July 1978.
(a) calculated, (b) measured, (c) mean monthly transport winds.

over a similar area (i.e. four 70- by 70-km grid squares), which in this particular case would give a calculated value of 59 $\mu g/m^3$.

- In some regions, the model underestimates concentrations. For example, in northwest Georgia, a measured value of 64 $\mu g/m^3$ is located near a calculated local maximum value of only 34. This may be because the measured value is unrepresentative, or because of the complexities of accurately modeling light wind situations. Also, some measured values in the west of the domain (e.g. the 23 near Wichita) appear to be reflecting local sulfur sources.
- In some regions, such as in western Kentucky, the model overestimates concentrations.
- The model does not accurately calculate the low measured values in the Appalachian region, probably because the current model assumes a flat terrain.

*July 1976*—The wind pattern for July 1976 [Figure 15(c)] is similar to that for July 1975 [Figure 14(c)]. However, the winds are generally much stronger, and the pattern shows a wave structure in the north. The calculated $SO_2$ concentrations for the July 1976 period [Figure 15(a)] are similar to those for July 1975 [Figure 14(a)]. However, the maximum values are generally lower, and the 16 $\mu g/m^3$ isoline moves distinctly eastward into the New York area, because of the stronger transport winds.

The measured $SO_2$ concentration values for July 1976 [Figure 15(b)] are very similar to those of July 1975 [Figure 14(b)]; for example, they both show relatively high values in the Pittsburgh, Cincinnati, Detroit, Atlanta, and St. Louis areas. The measured data for July 1976 generally agree favorably with the calculated results. As with July 1975, there are some differences between the measured and calculated: the low measured values over Lake Michigan do not agree with calculated values, and there is an apparently large, unrepresentative measured value in the west of the domain (a 42 $\mu g/m^3$ near Sioux City, Iowa). The measured $SO_2$ concentrations for July 1976 appear to be generally lower over the Pittsburgh area than those for July 1975, but show higher values over the New York area. This is consistent with the changes seen in the calculated field.

*August 1977*—The August mean winds for 1977 [Figure 16(c)] are very similar to those for July 1976. They appear to have about the same strength in the north as do the July 1976 winds, but do not show the wave structure. Because of this similarity in the transport winds, the calculated $SO_2$ concentration patterns for August 1977 [Figure 16(a)] are also very similar to those calculated for July 1976 [Figure 13(a)].

The measured $SO_2$ concentrations for August 1977 are similar to those for July in both 1975 and 1976. However, since the emission data are actually for the year 1977, the comparison of the calculated and measured values for August 1977 is more meaningful. The $SO_2$-concentration patterns of the model calculations compare quite favorably with the measured ones; for example, the pocket of low measured values along the Tennessee/Kentucky border appears in the calculated field, and the 41-$\mu g/m^3$ measured value in the central north of the domain is very close to the high calculated values ( $> 16$) near Rouyn, Quebec. However, as in the July 1975 and July 1976 periods, the calculated values show peak values that are higher than the listed measured values. There are also some significant differences between the calculated and measured concentrations at specific locations; for example, high measured values ( $\geqslant 16$ $\mu g/m^3$) are found all along the northeastern coast, while the comparable calculated values in this region occur only over the New York area.

The measured $SO_2$ concentration values for this August 1977 period are considerably lower than those for January 1977. The calculated values for August 1977 are also lower than those calculated for January 1977, but not by as much as the measured. This may suggest that the ENAMAP-1 model is not depicting the seasonal variation as accurately as might be desired--possibly because of the value assigned for the mixing height.

*July 1978*—The July winds for 1978 [Figure 16(c)] are very similar to the July winds for 1977, except that wind magnitudes are somewhat less in the north of the domain. Thus, the calculated $SO_2$ concentrations for July 1978 [Figure 17(a)] are very similar to those calculated for July 1975 [Figure 14(a)].

The measured $SO_2$ concentrations for July 1978 [Figure 17(b)] show some noticeable differences from the measured summer data for the previous years, and thus from the calculated results [Figure 17(a)]. In particular, there appears to have been a significant increase in $SO_2$ concentrations throughout the Midwest and the northeastern United States. As with January, these differences may be due to significant changes in the sulfur emissions for the year 1978.

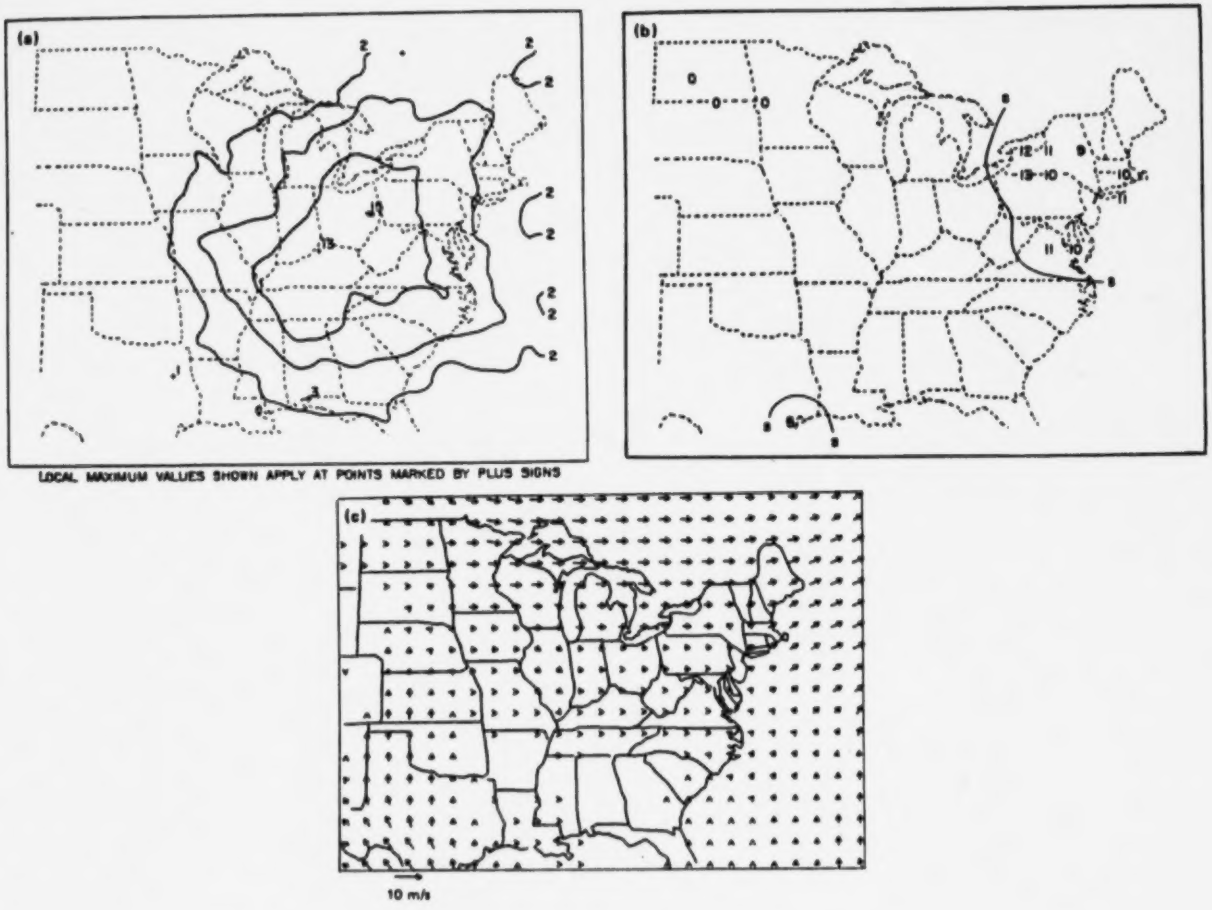
### $SO_4^=$ Concentrations

The calculated and measured $SO_4^=$ concentrations for the July months of the four years 1975, 1976, 1977, and 1978 are shown in Figures 18 through 21. Since the $SO_4^=$ concentration fields are strongly dependent on the transport wind field, the mean monthly wind charts are repeated in these figures for ease of comparison [e.g., Figure 18(c) is identical to Figure 14(c)]. Results for the calculated July $SO_4^=$ dry depositions, which are proportional to the $SO_4^=$ concentrations, are shown in Appendix A.

*July 1975*—The calculated $SO_4^=$ concentration pattern [Figure 18(a)] for July 1975 is a symmetrical one produced by the light winds (or variable wind direction) during the month. Comparison of the calculated and measured $SO_4^=$ concentrations for July 1975 [Figure 18(b)] is difficult because of the scarcity of measured data. However, the high measured values over the New England area are not in good agreement with the calculated values.

*July 1976*—The calculated $SO_4^=$-concentration pattern [Figure 19(a)] shows that the center of high values ( $> 8$ $\mu g/m^3$) is displaced to the southeast, lying principally over the Virginia area with a strip of relatively high values extending southwestward into Georgia. This can be attributed to the stronger winds [Figure 19(c)], which would have moved the emissions in this direction. The measured $SO_4^=$ concentrations for January 1976 [Figure 19(b)] are also incomplete, but do not appear to show the same southeast displacement as the calculated values. In the measured data, the major $SO_4^=$ pollution appears to be located over the highly $SO_2$-emitting Pittsburgh area. Also, as was noted for July 1975, the relatively high measurement of $SO_4^=$ values suggests either that the calculated values are slightly low or that the $SO_4^=$ measurements are somewhat biased by local $SO_4^=$ sources.

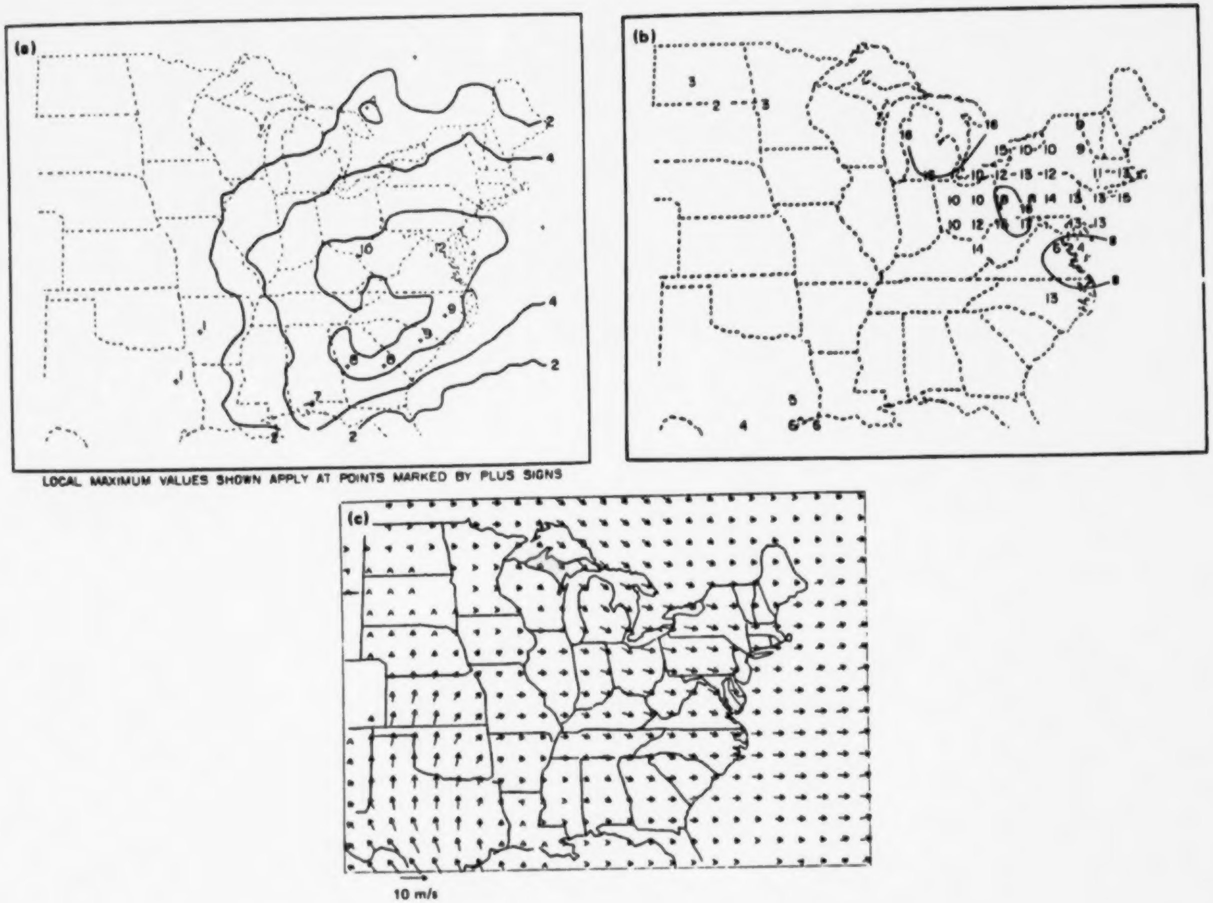
*August 1977*—The calculated $SO_4^=$ concentrations for August 1977 [Figure 20(a)] show a distinct southwest-to northeast elongation of the concentration isolines. ENAMAP-1 appears to have performed quite well in calculating these $SO_4^=$ concentrations for this summer period, since they compare very favorably with the measured values [Figure 20(b)]. The higher $SO_4^=$ concentrations ( $> 8$ $\mu g/m^3$) occur over the northeastern United States in both the calculated and measured fields, with peak values (17 $\mu g/m^3$) occurring near the Pittsburgh area. A region of low concentrations is indicated in both the calculated and measured fields over eastern Kentucky, although the measured concentrations are somewhat lower than the calculated.



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

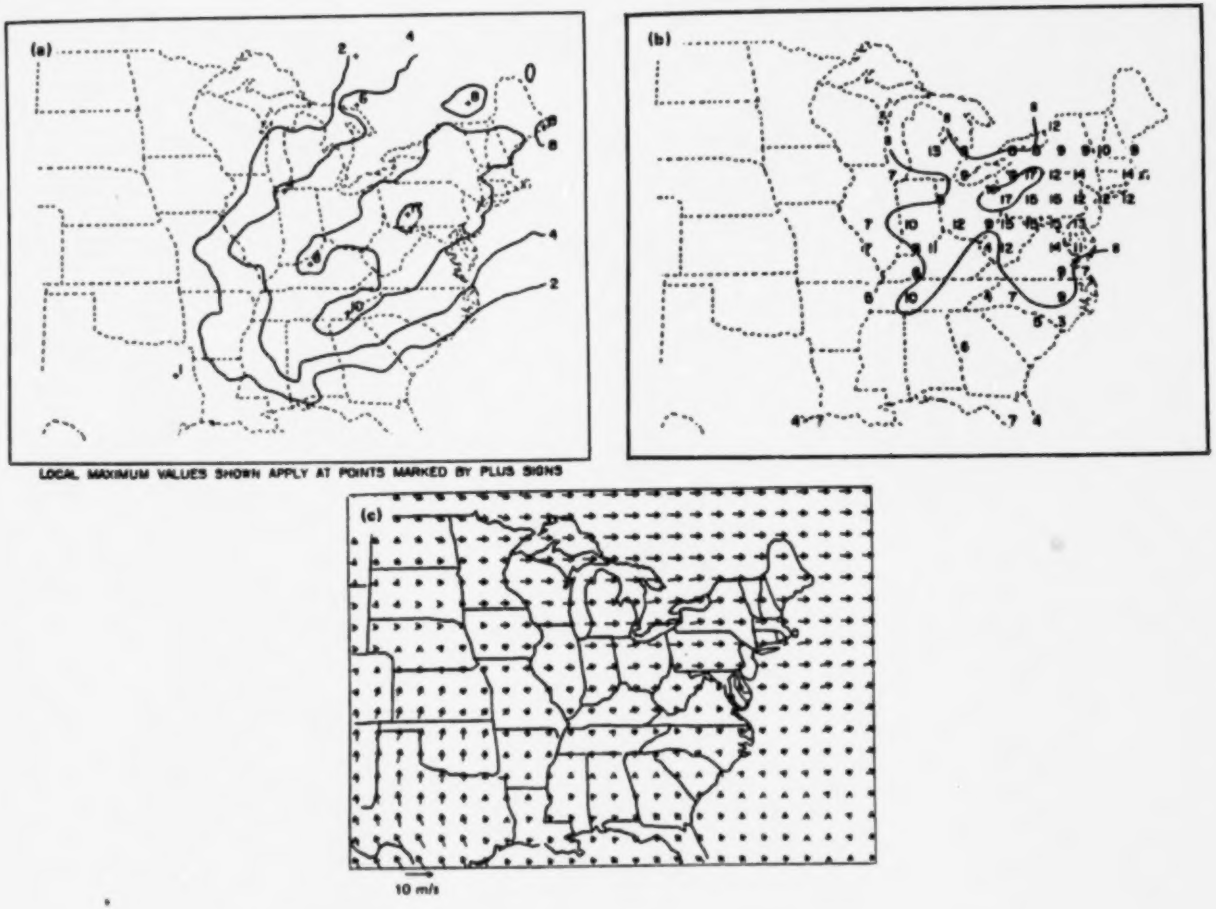
Figure 18. $SO_4^=$ concentrations ($\mu g/m^3$) for July 1975.

(a) calculated, (b) measured, (c) mean monthly transport winds.



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

Figure 19. $SO_4^=$ concentrations ($\mu g/m^3$) for July 1976.
(a) calculated, (b) measured, (c) mean monthly transport winds.



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

Figure 20. $SO_4^=$ concentrations ($\mu g/m^3$) for August 1977.
(a) calculated, (b) measured, (c) mean monthly transport winds.

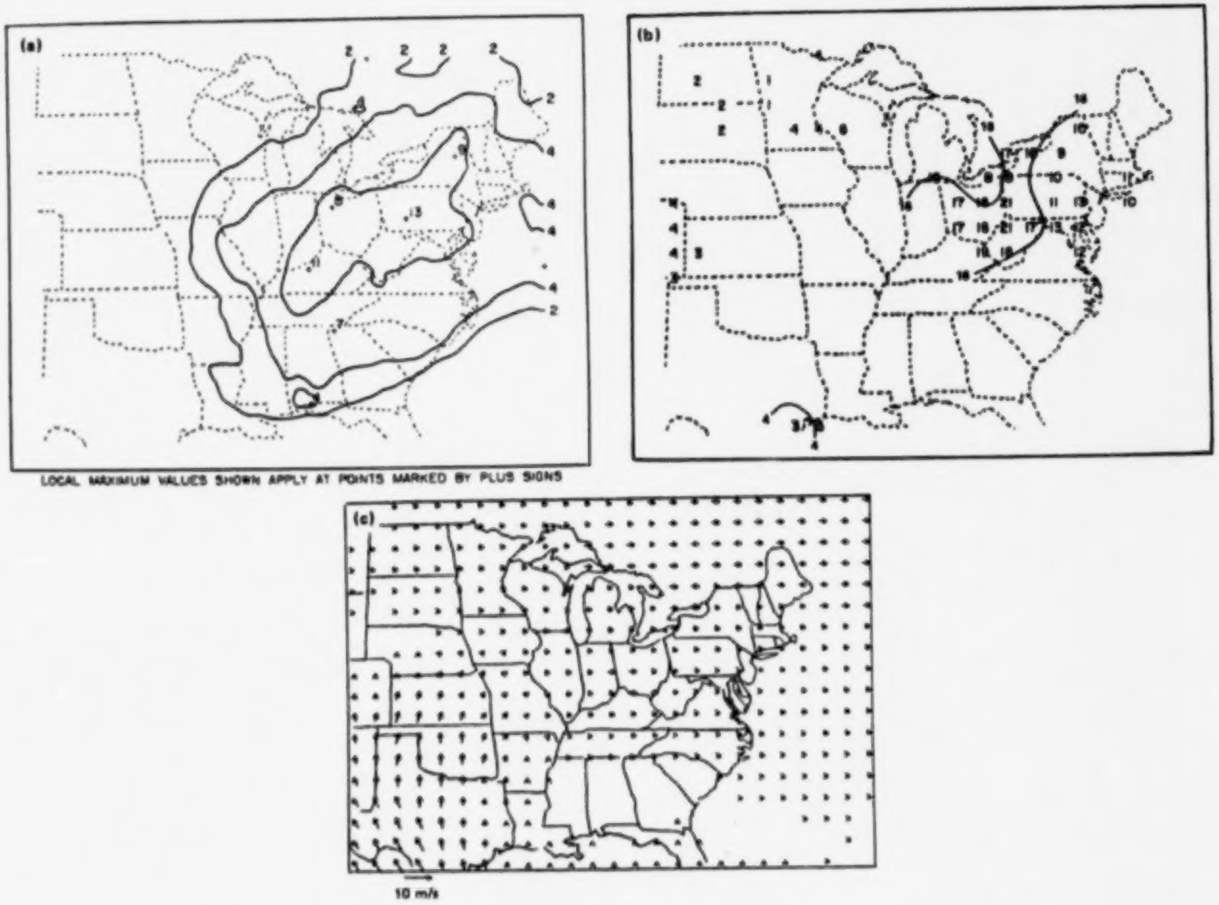

(a)
LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS
(b)
(c)
10 m/s

Figure 21. $SO_4^=$ concentrations ($\mu g/m^3$) for July 1978.
(a) calculated, (b) measured, (c) mean monthly transport winds.

*July 1978*—The calculated $SO_4^=$-concentration pattern for July 1978 [Figure 21(a)] is similar to that for 1977 [Figure 14(a)]. The available measured data for this period [Figure 21(b)] show a pattern that is reasonably consistent with the calculated one. However, the measured $SO_4^=$ values appear to be significantly higher than the calculated, possibly because of an increase in the sulfur emission in 1978 that was not accounted for in the model calculations.

### $SO_4^=$ Wet Depositions

The calculated $SO_4^=$ wet-deposition fields for the July months of the four years are shown in Figures 22 through 25, along with the total monthly precipitation amounts. (The calculated $SO_2$ wet-deposition fields are shown in Appendix A.)

*July 1975*—During this summer month, high monthly precipitation amounts ( > 64 mm) occurred in the southeast, along the East Coast, and along the easternmost Canadian/United States border [see Figure 22(b)]. The $SO_4^=$ wet-deposition pattern for this month [Figure 22(a)] is basically similar to the $SO_4^=$ concentration pattern [Figure 18(a)]. However, the $SO_4^=$ wet depositions show more spottiness and higher values along the high precipitation areas mentioned above. In particular, maximum values occur along Lakes Erie and Ontario in areas of high precipitation. Precipitation is also reflected in the $SO_4^=$ wet-deposition pattern at other locations; for example, the low precipitation amounts over northwestern Missouri and northwestern Wisconsin appear to have resulted in low wet depositions of $SO_4^=$ in these same areas.

Rain amounts in the westernmost part of the domain (particularly the southwest part) were considerably higher during July of 1975 than during the January 1975 period (see Figure 10). Consequently, the July 1975 $SO_4^=$ wet-deposition pattern shows higher values over this western section than does the January 1975 pattern.

*July 1976*—During this summer month, some high monthly precipitation amounts ( >64 mm) occurred in the South and along and off the East Coast [Figure 23(b)]. The effect of this precipitation is reflected in the $SO_4^=$ wet depositions [Figure 23(a)]. The largest values extend from the Pittsburgh area on into the Atlantic Ocean consistent with areas of higher precipitation. The greater rain amounts in the South appear to have produced greater wet depositions in this section of the U.S. Also, the tongue of high $SO_4^=$ wet depositions that protrudes into Nebraska and South Dakota coincides with a band of relatively high precipitation amounts along the same area.

*August 1977*—During this summer month, an area of high precipitation ( > 64 mm) occurred along the south and southeast coast and within the center of the domain [Figure 23(b)]. The effects of these precipitation amounts are readily apparent in the $SO_4^=$ wet-deposition pattern [Figure 23(a)]. In particular, the $SO_4^=$ wet deposition field for the August 1977 period shows some relatively high values in the interior of the domain that do not appear in the $SO_4^=$ concentrations [Figure 18(a)]. The low wet-deposition amounts located off the southern coast are probably caused by southerly winds, which did not transport any pollutant into the area. Although highest $SO_4^=$ concentrations occurred in areas near Pittsburgh, the highest $SO_4^=$ wet deposition occurred in New York State, where the precipitation amounts were higher.

*July 1978*—During this summer month, there were high precipitation amounts ( > 64 mm) over the southeastern coastal areas and over the northeastern part of the domain [Figure 24(b)]. This precipitation pattern is again reflected in the $SO_4^=$ wet-deposition pattern [Figure

24(a)]. However, the highest $SO_4^=$ wet depositions, and the patterns in general, closely follow those of the $SO_4^=$ concentrations [Figure 21(a)].

### Interregional Exchanges

Table 3(a) through (d) shows the total sulfur exchanges between the different regions of Figure 1 for the July months of the years 1975, 1976, 1977 (August), and 1978. Table 3(a) shows that during July 1975, 56.0 ktons, or 70.3 percent, of the total sulfur deposition within the V-North region came from its own emissions. Region V-North also received 14.1 ktons, or 17.7 percent, from Region V-South; 3.9 ktons, or 4.9 percent, from Region VII and S. Ontario; and the remainder (2.2 percent) from the other regions.

Table 3(a) through (d) provides an indication of the year-to-year changes for the July month. For example, it shows that S. Quebec produced 57 percent of the sulfur deposited within its area in July 1976, but only 40 percent in August 1977. This again illustrates the importance of the change in winds and precipitation rate from year to year.

### Summary

The mean July wind patterns were fairly similar for all four years, except for differences in the mean wind vector magnitudes. Consequently, the mean measured July $SO_2$-concentration patterns and $SO_4^=$-concentration patterns were also similar; however, the $SO_4^=$ concentrations showed some yearly variations.

The calculated and measured $SO_2$ concentrations appear to show reasonable agreement during all the July periods, but with noticeable differences. The calculated and measured $SO_4^=$ concentrations appear to be in reasonable agreement during the August 1977 and July 1978 periods, but not during the other two summer periods (July 1975 and July 1976). Possible causes of the differences between calculated and measured $SO_2$ and $SO_4^=$ concentrations were discussed in the January summary.

The July monthly precipitation amounts for the four years generally showed relatively high values along the southern and eastern coasts. However, there were considerable changes in the July precipitation patterns from year to year that were generally reflected in the $SO_4^=$ wet-deposition patterns.

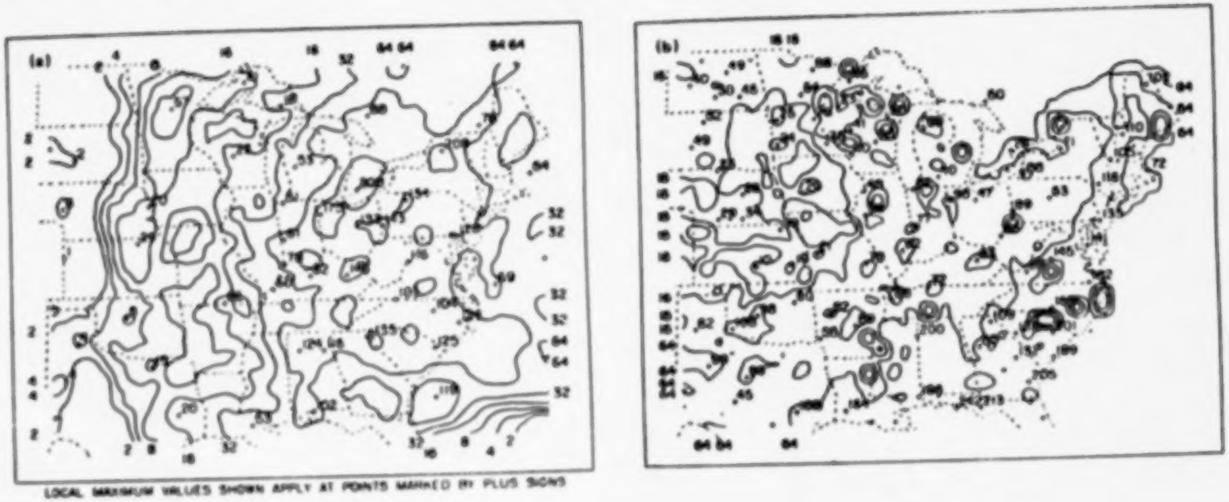

(a)
(b)
LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

Figure 22. $SO_4^{=}$ wet depositions for July 1975.

(a) calculated $SO_4$ wet depositions ($mg/m^2$), (b) precipitation (mm/month).

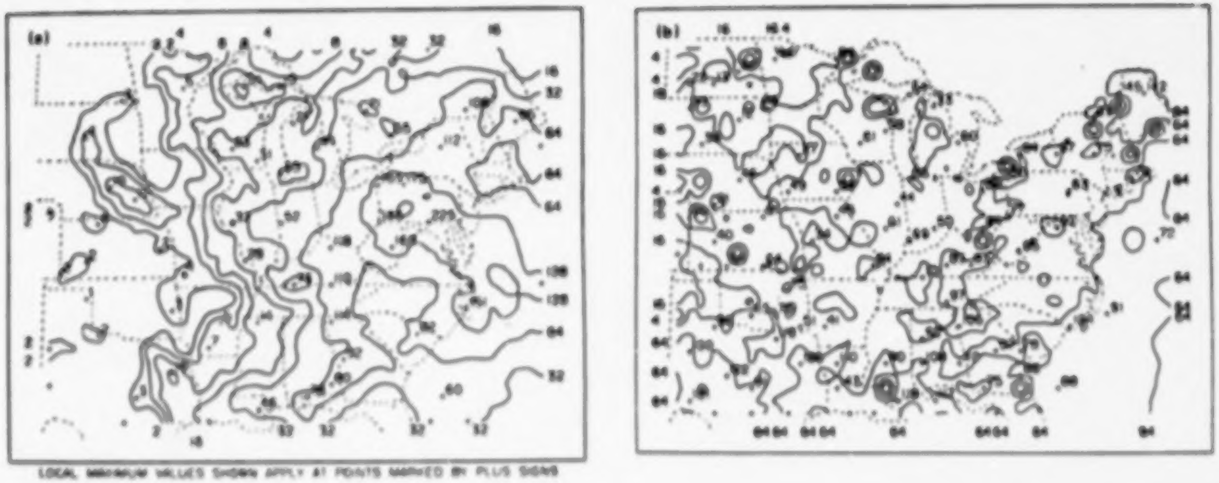
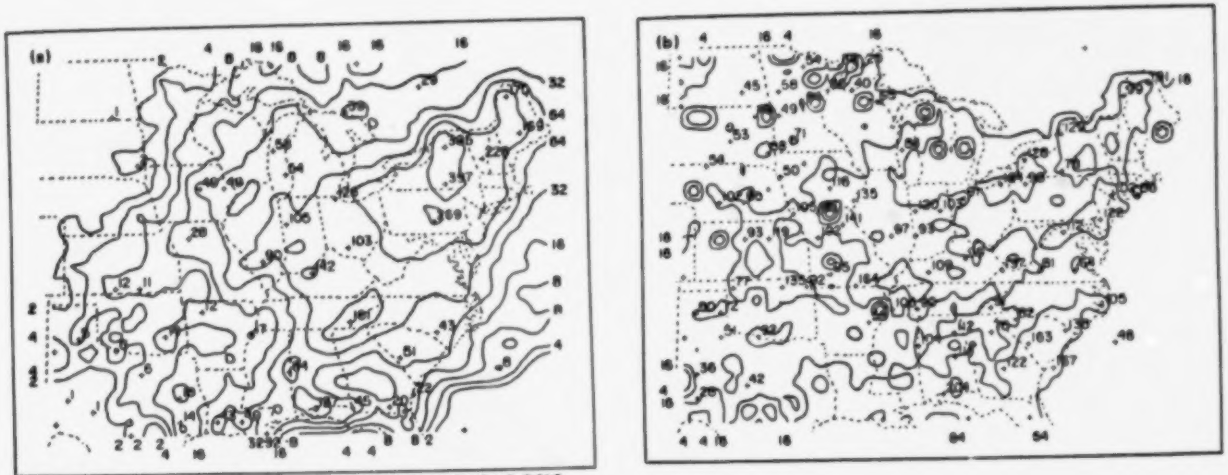

(a)
(b)
LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

Figure 23. $SO_4^=$ wet depositions for July 1976.

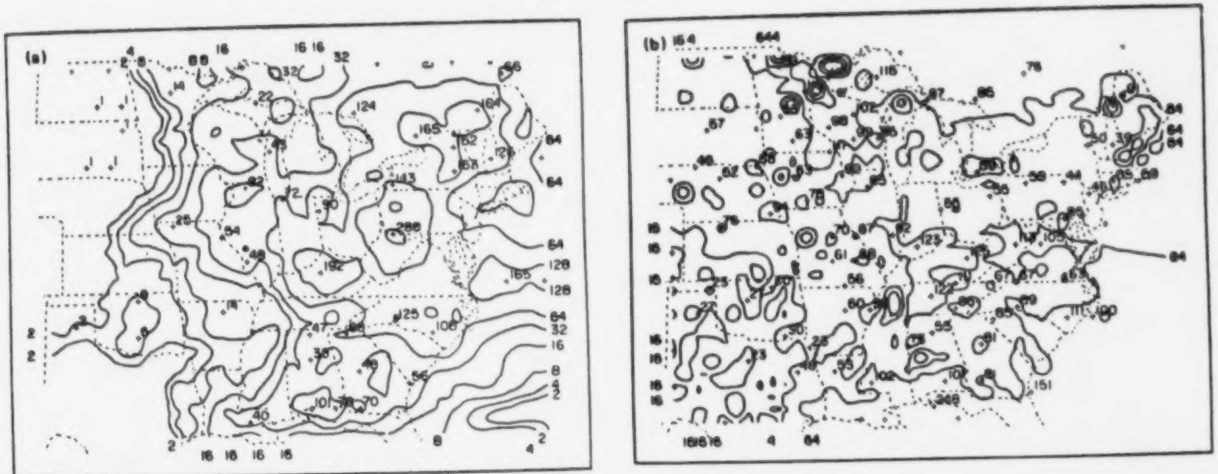
(a) calculated $SO_4^=$ wet depositions ($mg/m^2$), (b) precipitation (mm/month).



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

Figure 24. $SO_4^=$ wet depositions for July 1977.

(a) calculated $SO_4^=$ wet depositions (mg/m$^2$), (b) precipitation (mm/month).



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

Figure 25. $SO_4^=$ wet depositions for July 1978.

(a) calculated $SO_4^=$ wet depositions ($mg/m^2$), (b) precipitation (mm/month).

## TABLE 3. CALCULATED INTERREGIONAL EXCHANGES OF SULFUR FOR JULY 1975, 1976, 1977, 1978*

### (a) JULY 1975

TOTAL CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS (kilotons)

| EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 VIII-NORTH | 6 | .0 | .0 | .1 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 2 V-NORTH | .0 | 56.0 | 28.4 | 2.6 | 0.0 | .1 | 20.5 | .3 | 2.2 | 5.5 | 1.6 | .4 | 2.2 |
| 3 S. ONTARIO | .0 | 3.9 | 80.1 | 0.0 | 0.0 | .0 | 3.7 | .0 | .3 | 3.9 | 3.7 | 1.1 | 6.2 |
| 4 VII | .2 | 3.9 | 1.5 | 32.4 | .0 | 2.5 | 8.9 | 2.5 | 3.3 | .2 | .0 | .1 | .3 |
| 5 VIII-SOUTH | 0.0 | 0.0 | 0.0 | .0 | .0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 VI-EAST | .2 | .3 | .1 | 1.9 | .1 | 38.4 | .3 | 3.9 | .2 | .0 | .0 | .0 | .0 |
| 7 V-SOUTH | .1 | 14.1 | 13.2 | 16.3 | .0 | .8 | 142.3 | 5.9 | 45.1 | 32.7 | 4.9 | .8 | 1.9 |
| 8 IV-SOUTH | .1 | .1 | .1 | .7 | .0 | 5.2 | 1.2 | 108.0 | 23.2 | .9 | .2 | .1 | .0 |
| 9 IV-NORTH | .1 | 1.2 | 1.2 | 3.5 | .0 | 2.5 | 21.8 | 10.3 | 90.8 | 9.3 | .6 | .2 | .4 |
| 10 III | .0 | .2 | 8.9 | .1 | .0 | .1 | 19.4 | .7 | 12.5 | 121.0 | 15.2 | 4.2 | 2.3 |
| 11 II | 0.0 | 0.0 | 5.5 | 0.0 | 0.0 | 0.0 | .0 | .1 | .5 | 3.1 | 18.1 | 6.0 | 1.6 |
| 12 I | 0.0 | 0.0 | .0 | 0.0 | 0.0 | .0 | 0.0 | .0 | .2 | .4 | 6.0 | 15.5 | 2.4 |
| 13 S QUEBEC | 0.0 | 0.0 | 9.6 | 0.0 | 0.0 | 0.0 | .0 | 0.0 | .0 | .1 | .3 | 1.4 | 17.0 |
| TOTAL (KTON S) | 1.3 | 79.7 | 148.8 | 57.7 | .2 | 49.6 | 218.1 | 131.7 | 178.4 | 176.9 | 50.7 | 29.8 | 34.4 |

PERCENT CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS

| EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 VIII-NORTH | 49.2 | .0 | .0 | .1 | 2.0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 2 V-NORTH | 1.0 | 70.3 | 19.1 | 4.6 | 0.0 | .1 | 9.4 | .2 | 1.2 | 3.1 | 3.2 | 1.2 | 6.3 |
| 3 S. ONTARIO | .0 | 4.9 | 53.9 | 0.0 | 0.0 | .0 | 1.7 | .0 | .2 | 2.2 | 7.2 | 3.8 | 18.0 |
| 4 VII | 16.0 | 4.9 | 1.0 | 56.2 | .8 | 5.0 | 4.1 | 1.9 | 1.8 | .1 | .1 | .2 | .9 |
| 5 VIII-SOUTH | 0.0 | 0.0 | 0.0 | .0 | 1.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 VI-EAST | 14.2 | .4 | .1 | 3.4 | 82.6 | 77.6 | .1 | 3.0 | .1 | .0 | .0 | .0 | .1 |
| 7 V-SOUTH | 7.1 | 17.7 | 8.9 | 28.3 | .9 | 1.7 | 65.3 | 4.5 | 25.3 | 18.5 | 9.6 | 2.8 | 5.6 |
| 8 IV-SOUTH | 5.2 | .2 | .1 | 1.2 | 9.4 | 10.5 | .5 | 82.0 | 13.0 | .5 | .4 | .3 | .1 |
| 9 IV-NORTH | 6.2 | 1.5 | .8 | 6.0 | 2.9 | 5.1 | 10.0 | 7.8 | 50.9 | 5.2 | 1.3 | .7 | 1.1 |
| 10 III | 1.1 | .2 | 6.0 | .2 | .0 | .1 | 8.9 | .5 | 7.0 | 68.4 | 29.9 | 14.1 | 6.7 |
| 11 II | 0.0 | 0.0 | 3.7 | 0.0 | 0.0 | 0.0 | .0 | .1 | .3 | 1.7 | 35.8 | 20.2 | 4.7 |
| 12 I | 0.0 | 0.0 | .0 | 0.0 | 0.0 | .0 | 0.0 | .0 | .1 | .2 | 11.8 | 52.1 | 7.1 |
| 13 S. QUEBEC | 0.0 | 0.0 | 6.4 | 0.0 | 0.0 | 0.0 | .0 | 0.0 | .0 | .0 | .6 | 4.7 | 49.4 |

TABLE 3 (continued)

(b) JULY 1976

TOTAL CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS (kilotons)

| EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 VIII-NORTH | .6 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 0.0 | 0.0 | 0.0 |
| 2 V-NORTH | .7 | 50.1 | 21.5 | 4.4 | .0 | .1 | 23.8 | .4 | 2.2 | 9.2 | 2.7 | 1.0 | 1.3 |
| 3 S. ONTARIO | .0 | 5.4 | 71.5 | .1 | 0.0 | .0 | 4.8 | .0 | .7 | 7.2 | 5.1 | 1.6 | 5.1 |
| 4 VII | .4 | 3.3 | .9 | 28.4 | .0 | 1.4 | 14.4 | 1.1 | 3.8 | 1.7 | .1 | .0 | .1 |
| 5 VIII-SOUTH | 0.0 | 0.0 | 0.0 | .0 | .0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 VI-EAST | .1 | .2 | .1 | 2.6 | .1 | 38.1 | .5 | 5.0 | .8 | .1 | .0 | .0 | .0 |
| 7 V-SOUTH | .1 | 7.9 | 6.6 | 11.9 | .0 | 2.5 | 124.7 | 5.2 | 47.1 | 53.2 | 4.5 | 2.0 | 1.0 |
| 8 IV-SOUTH | 0.0 | 0.0 | 0.0 | .0 | 0.0 | 1.3 | .0 | 104.4 | 17.1 | .1 | .0 | .0 | 0.0 |
| 9 IV-NORTH | .0 | .0 | .2 | .2 | .0 | .9 | 10.7 | 12.7 | 89.6 | 14.6 | .9 | .2 | .0 |
| 10 III | 0.0 | .0 | 1.0 | .0 | 0.0 | .0 | 15.8 | .1 | 13.7 | 119.2 | 9.8 | 3.9 | .8 |
| 11 II | 0.0 | .0 | 4.3 | .0 | 0.0 | .0 | .1 | 0.0 | .1 | 3.3 | 17.9 | 4.7 | 1.2 |
| 12 I | 0.0 | .0 | .0 | .0 | 0.0 | .0 | .0 | 0.0 | .0 | .4 | 5.1 | 15.3 | 1.7 |
| 13 S. QUEBEC | 0.0 | .1 | 12.3 | .0 | 0.0 | .0 | .1 | .0 | .0 | .1 | .8 | 1.4 | 14.8 |
| TOTAL (KTON S) | 1.9 | 67.0 | 118.3 | 47.6 | .2 | 44.3 | 194.8 | 128.9 | 175.1 | 209.2 | 46.7 | 30.0 | 25.9 |

PERCENT CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS

| EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 VIII-NORTH | 32.5 | .1 | .0 | .1 | .0 | .0 | .0 | .0 | .0 | .0 | 0.0 | 0.0 | 0.0 |
| 2 V-NORTH | 35.5 | 74.8 | 18.2 | 9.2 | .1 | .3 | 12.2 | .3 | 1.2 | 4.4 | 5.7 | 3.2 | 4.8 |
| 3 S. ONTARIO | .0 | 8.1 | 60.4 | .2 | 0.0 | .1 | 2.4 | .0 | .4 | 3.4 | 11.0 | 5.2 | 19.8 |
| 4 VII | 21.3 | 4.9 | .8 | 59.7 | 14.9 | 3.1 | 7.4 | .8 | 2.2 | .8 | .3 | .1 | .2 |
| 5 VIII-SOUTH | 0.0 | 0.0 | 0.0 | .0 | 1.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 VI-EAST | 5.5 | .2 | .0 | 5.5 | 80.4 | 86.0 | .3 | 3.8 | .5 | .1 | .0 | .0 | .0 |
| 7 V-SOUTH | 5.3 | 11.8 | 5.6 | 25.0 | 3.3 | 5.6 | 64.0 | 4.0 | 26.9 | 25.4 | 9.6 | 6.6 | 3.8 |
| 8 IV-SOUTH | 0.0 | 0.0 | 0.0 | .0 | 0.0 | 2.9 | .0 | 81.0 | 9.8 | .0 | .0 | .0 | 0.0 |
| 9 IV-NORTH | .0 | .0 | .2 | .3 | .0 | 2.0 | 5.5 | 9.9 | 51.2 | 7.0 | 1.8 | .5 | .0 |
| 10 III | 0.0 | .0 | .8 | .0 | 0.0 | .0 | 8.1 | .1 | 7.8 | 57.0 | 20.9 | 13.1 | 2.9 |
| 11 II | 0.0 | .0 | 3.6 | .0 | 0.0 | .0 | .1 | 0.0 | .0 | 1.6 | 38.2 | 15.7 | 4.7 |
| 12 I | 0.0 | .0 | .0 | .0 | 0.0 | .0 | .0 | 0.0 | .0 | .2 | 10.8 | 51.0 | 6.5 |
| 13 S. QUEBEC | 0.0 | .2 | 10.4 | .0 | 0.0 | .0 | .0 | .0 | .0 | .1 | 1.6 | 4.6 | 57.1 |

TABLE 3 (continued)

(c) AUGUST 1977

TOTAL CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS (kilotons)

| EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 VIII-NORTH | .9 | .0 | .0 | .1 | .0 | .0 | .0 | 0.0 | .0 | .0 | .0 | .0 | .0 |
| 2 V-NORTH | .0 | 59.9 | 29.5 | 1.6 | 0.0 | .1 | 14.8 | .2 | .6 | 4.1 | 4.5 | 1.4 | 3.5 |
| 3 S. ONTARIO | .0 | 2.9 | 65.5 | 0.0 | 0.0 | 0.0 | 2.1 | .0 | .1 | 3.7 | 6.4 | 3.6 | 12.4 |
| 4 VII | .0 | 4.3 | 1.3 | 33.7 | .0 | 1.1 | 15.6 | .2 | .7 | .3 | .3 | .2 | .2 |
| 5 VIII-SOUTH | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 VI-EAST | .1 | .3 | .1 | 4.5 | .1 | 42.3 | .9 | 2.4 | .3 | .1 | .0 | .0 | .0 |
| 7 V-SOUTH | 0.0 | 15.7 | 15.2 | 9.7 | 0.0 | 1.2 | 147.4 | 1.8 | 26.2 | 44.4 | 12.3 | 3.9 | 3.2 |
| 8 IV-SOUTH | 0.0 | .2 | .9 | .8 | 0.0 | 3.1 | 2.6 | 103.1 | 36.5 | 3.6 | .3 | .1 | .5 |
| 9 IV-NORTH | 0.0 | .4 | 2.9 | .4 | 0.0 | 1.3 | 22.9 | 4.9 | 85.2 | 19.7 | 2.7 | .8 | 1.0 |
| 10 III | 0.0 | 0.0 | 1.8 | 0.0 | 0.0 | 0.0 | 11.5 | .2 | 5.9 | 134.9 | 23.9 | 7.9 | 1.1 |
| 11 II | 0.0 | 0.0 | 4.1 | 0.0 | 0.0 | 0.0 | 0.0 | .0 | .1 | 1.7 | 19.8 | 7.6 | 1.4 |
| 12 I | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .0 | .0 | 5.2 | 16.6 | 1.2 |
| 13 S. QUEBEC | 0.0 | 0.0 | 5.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .2 | 1.9 | 16.3 |
| TOTAL (KTON S) | 1.0 | 83.8 | 126.9 | 50.9 | .1 | 49.1 | 217.8 | 112.8 | 155.5 | 212.3 | 75.6 | 44.1 | 40.7 |

PERCENT CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS

| EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 VIII-NORTH | 88.7 | .1 | .0 | .2 | .4 | .0 | .0 | 0.0 | .0 | .0 | .0 | .0 | .0 |
| 2 V-NORTH | 1.2 | 71.5 | 23.3 | 3.1 | 0.0 | .2 | 6.8 | .1 | .4 | 1.9 | 5.9 | 3.2 | 8.6 |
| 3 S. ONTARIO | .0 | 3.5 | 51.6 | 0.0 | 0.0 | 0.0 | 1.0 | .0 | .1 | 1.7 | 8.5 | 8.2 | 30.3 |
| 4 VII | 2.0 | 5.2 | 1.0 | 66.3 | .0 | 2.2 | 7.2 | .1 | .4 | .2 | .4 | .4 | .5 |
| 5 VIII-SOUTH | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 VI-EAST | 8.1 | .4 | .1 | 8.8 | 99.6 | 86.1 | .4 | 2.1 | .2 | .0 | .0 | .0 | .1 |
| 7 V-SOUTH | 0.0 | 18.7 | 12.0 | 19.1 | 0.0 | 2.5 | 67.7 | 1.6 | 16.8 | 20.9 | 16.3 | 8.8 | 7.8 |
| 8 IV-SOUTH | 0.0 | .2 | .7 | 1.6 | 0.0 | 6.4 | 1.2 | 91.5 | 23.5 | 1.7 | .4 | .3 | 1.3 |
| 9 IV-NORTH | 0.0 | .5 | 2.3 | .8 | 0.0 | 2.6 | 10.5 | 4.3 | 54.8 | 9.3 | 3.6 | 1.9 | 2.4 |
| 10 III | 0.0 | 0.0 | 1.4 | 0.0 | 0.0 | 0.0 | 5.3 | .1 | 3.8 | 63.5 | 31.7 | 17.9 | 2.7 |
| 11 II | 0.0 | 0.0 | 3.2 | 0.0 | 0.0 | 0.0 | 0.0 | .0 | .0 | .8 | 26.1 | 17.3 | 3.4 |
| 12 I | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .0 | .0 | 6.9 | 37.7 | 2.9 |
| 13 S. QUEBEC | 0.0 | 0.0 | 4.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .2 | 4.3 | 40.1 |

## TABLE 3 (concluded)

### (d) JULY 1978

TOTAL CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS (kilotons)

| EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 VIII-NORTH | .7 | .1 | .0 | .1 | .0 | .0 | .0 | .0 | .0 | .0 | 0.0 | 0.0 | .0 |
| 2 V-NORTH | .0 | 60.1 | 28.9 | 3.1 | 0.0 | .0 | 19.1 | .1 | 2.0 | 4.1 | 1.9 | .6 | 1.8 |
| 3 S ONTARIO | .0 | 5.9 | 80.2 | .0 | 0.0 | .0 | 4.3 | .0 | .5 | 3.7 | 3.0 | .9 | 6.1 |
| 4 VII | .0 | 3.6 | 1.2 | 33.9 | .0 | .6 | 13.6 | .3 | 2.3 | .8 | .3 | .1 | .3 |
| 5 VIII-SOUTH | 0.0 | 0.0 | 0.0 | .0 | .0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 VI-EAST | .1 | .2 | .0 | 3.9 | .1 | 37.5 | .4 | 5.0 | .5 | .1 | .0 | .0 | .0 |
| 7 V-SOUTH | 0.0 | 11.7 | 14.4 | 11.5 | 0.0 | .9 | 145.5 | 2.0 | 35.7 | 41.5 | 8.3 | 1.8 | 3.1 |
| 8 IV-SOUTH | .0 | .1 | .1 | .9 | .0 | 3.0 | 1.7 | 105.0 | 28.8 | 1.8 | .1 | .1 | .0 |
| 9 IV-NORTH | 0.0 | .1 | 1.1 | .8 | 0.0 | 1.6 | 20.5 | 6.9 | 92.5 | 13.3 | 1.2 | .3 | .2 |
| 10 III | 0.0 | .0 | 2.4 | .0 | 0.0 | .0 | 16.8 | .5 | 10.9 | 125.0 | 16.3 | 6.2 | 3.2 |
| 11 II | 0.0 | .1 | 5.4 | .0 | 0.0 | .0 | .2 | .1 | .2 | 3.6 | 16.8 | 5.8 | 1.3 |
| 12 I | 0.0 | .0 | .3 | 0.0 | 0.0 | .0 | .0 | .0 | .0 | .5 | 5.3 | 14.3 | 1.7 |
| 13 S QUEBEC | 0.0 | 0.0 | 11.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .0 | .3 | 1.0 | 16.1 |
| TOTAL (KTON S) | .8 | 81.9 | 145.4 | 54.2 | .1 | 43.5 | 222.1 | 119.8 | 173.4 | 194.5 | 53.5 | 31.1 | 33.6 |

PERCENT CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS

| EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 VIII-NORTH | 80.9 | .1 | .0 | .1 | .3 | .0 | .0 | .0 | .0 | .0 | 0.0 | 0.0 | .0 |
| 2 V-NORTH | 3.3 | 73.4 | 19.8 | 5.7 | 0.0 | .0 | 8.6 | .1 | 1.2 | 2.1 | 3.5 | 1.9 | 5.2 |
| 3 S ONTARIO | .0 | 7.3 | 55.1 | .0 | 0.0 | .0 | 1.9 | .0 | .3 | 1.9 | 5.6 | 3.0 | 18.0 |
| 4 VII | 4.4 | 4.4 | .8 | 62.6 | .0 | 1.3 | 6.1 | .3 | 1.3 | .4 | .5 | .2 | .8 |
| 5 VIII-SOUTH | 0.0 | 0.0 | 0.0 | .0 | 1.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 VI-EAST | 11.5 | .2 | .0 | 7.1 | 97.8 | 86.0 | .2 | 4.1 | .3 | .1 | .0 | .0 | .0 |
| 7 V-SOUTH | 0.0 | 14.3 | 9.9 | 21.3 | 0.0 | 2.0 | 65.5 | 1.6 | 20.6 | 21.3 | 15.6 | 5.7 | 9.3 |
| 8 IV-SOUTH | .0 | .1 | .1 | 1.6 | .2 | 6.9 | .8 | 87.6 | 16.6 | .9 | .2 | .3 | .0 |
| 9 IV-NORTH | 0.0 | .2 | .8 | 1.5 | 0.0 | 3.6 | 9.2 | 5.8 | 53.4 | 6.8 | 2.3 | .8 | .6 |
| 10 III | 0.0 | .0 | 1.7 | .1 | 0.0 | .0 | 7.6 | .4 | 6.3 | 64.3 | 30.4 | 20.1 | 9.4 |
| 11 II | 0.0 | .1 | 3.7 | .0 | 0.0 | .0 | .1 | .1 | .1 | 1.8 | 31.3 | 18.7 | 3.8 |
| 12 I | 0.0 | .0 | .2 | 0.0 | 0.0 | .0 | .0 | .0 | .0 | .3 | 9.9 | 46.0 | 5.0 |
| 13 S QUEBEC | 0.0 | 0.0 | 7.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .0 | .6 | 3.3 | 47.9 |

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*All results are based on emission data for 1977. A value of 0.0 in the tables indicates no sulfur deposition occurred; a value of .0 signifies a sulfur deposition of less than 0.05 ktons.

# SECTION 6

## RESULTS FOR THE TRANSITIONAL MONTHS (1976-1978)

The results for the two transitional months (April and October) for the years 1975, 1976, 1977, and 1978 are shown in Figures 26 through 49 and in Tables 4 and 5. These results, which are of the same type as those given for January and July, consist of:

- Calculated and measured $SO_2$ concentrations and mean vector winds for April (Figures 26 through 29) and for October (Figures 30 through 33).
- Calculated and measured $SO_4^=$ concentrations and mean vector winds for April (Figures 34 through 37) and for October (Figures 38 through 41).
- Calculated $SO_4^=$ wet depositions and precipitation amounts for April (Figures 42 through 45) and for October (Figures 46 through 49).
- Calculated sulfur interregional exchanges for April (Table 4) and for October (Table 5).

The graphical results for the $SO_2$ and $SO_4^=$ dry depositions and the $SO_2$ wet depositions are shown in Appendix A.

The April mean wind fields [part (c) of Figures 26 to 29] for the four years are similar, depicting cyclonic flow in the northeastern part of the domain and anticyclonic flow in the South. However, the wind pattern for April 1977 [Figure 28(c)] does not show a pronounced cyclonic flow in the Northeast and, upon close inspection, is actually more similar to the summer wind pattern [part (c) of Figures 14 to 17]. The April 1975 wind pattern shows a distinct deformational pattern with a col located approximately in the northwestern corner of Illinois. The April 1975 and 1978 wind patterns both show a very strong confluence of the winds over the Virginias.

The October 1975 mean wind pattern [Figure 30(c)] is very similar to the April mean wind patterns, particularly that of April 1975 [Figure 26(c)]. However, the October mean wind fields for the other three years [part (c) of Figures 31 to 33] show very light or zero winds in the south, and westerly winds in the north that are fairly light in October 1976 and fairly strong in October 1978. The October 1978 mean wind field actually tends to portray a more winter-like flow.

The $SO_2$ concentrations for the transitional months [part (a) of Figures 26 to 33] principally depict the regions of high emission. However, they show some pattern distortion caused by wind transport; for example, the $SO_2$ concentration patterns for all of the April months and for the October 1975 month show a protrusion of the 16-$\mu g/m^3$ isoline toward the southeast into the Virginias. The measured $SO_2$ concentrations for these transitional months [part (b) of Figures 26 to 33] generally show good correspondence with the calculated, particularly for some of the months such as April 1976. However, there are some noticeable discrepancies. The calculations do not depict the high measured value over northern Arkansas in both April

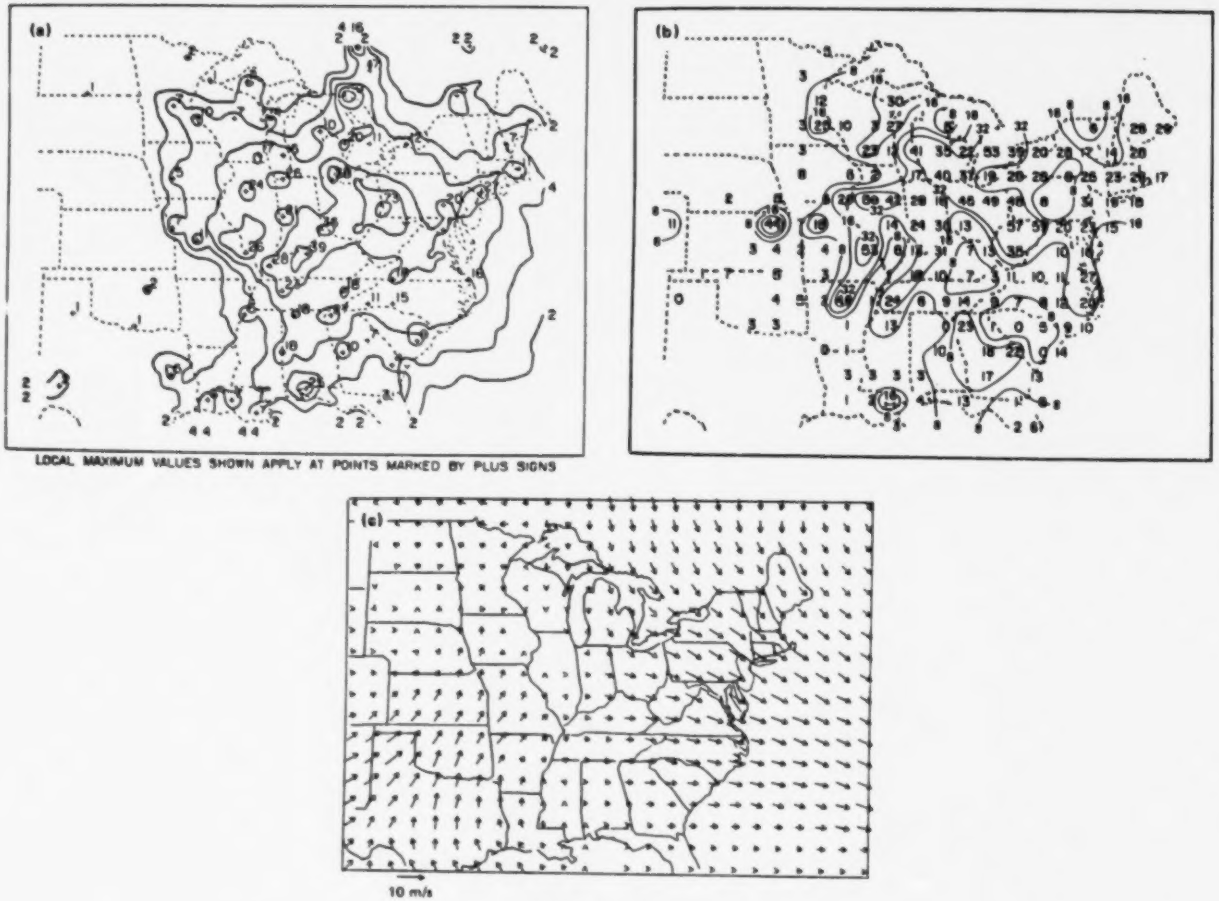
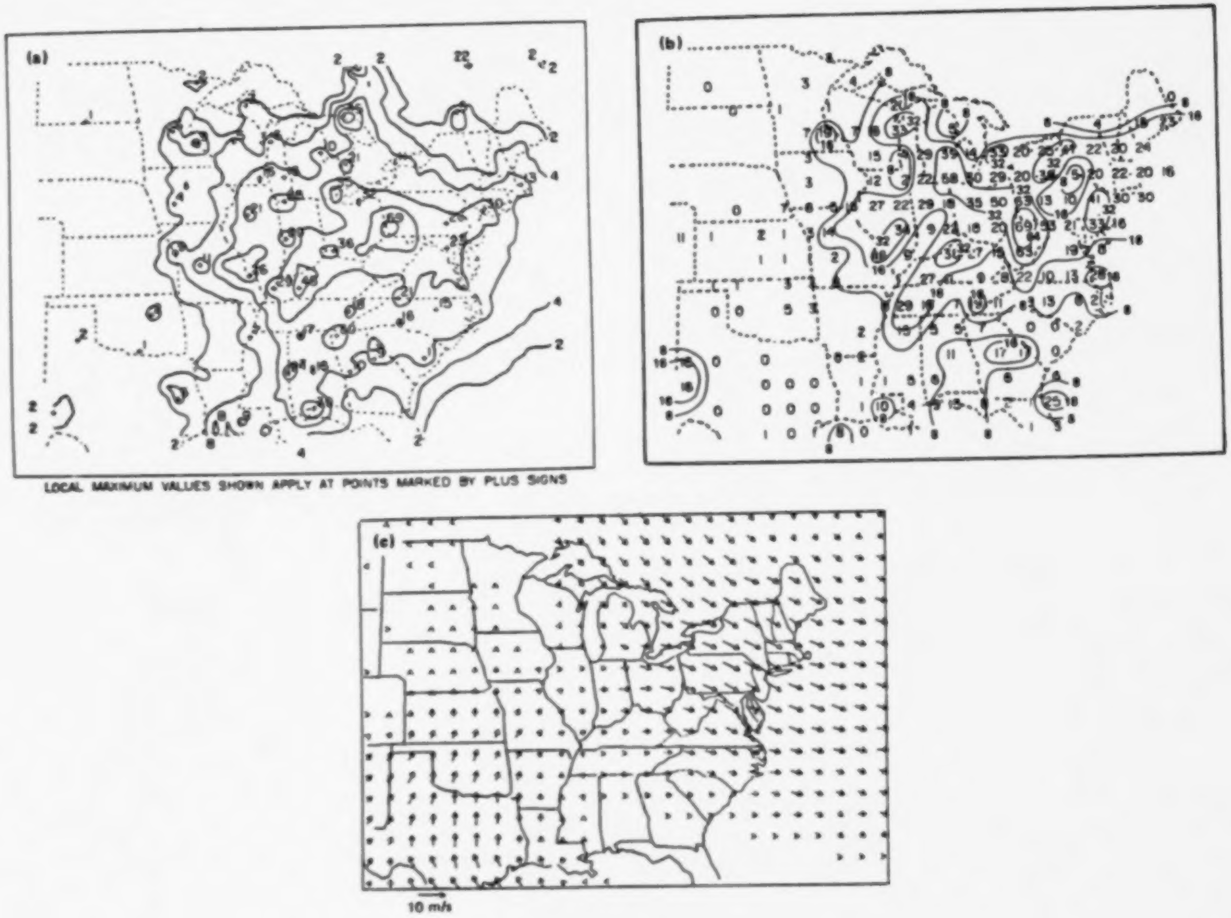

(a)
(b)
LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS
(c)
10 m/s

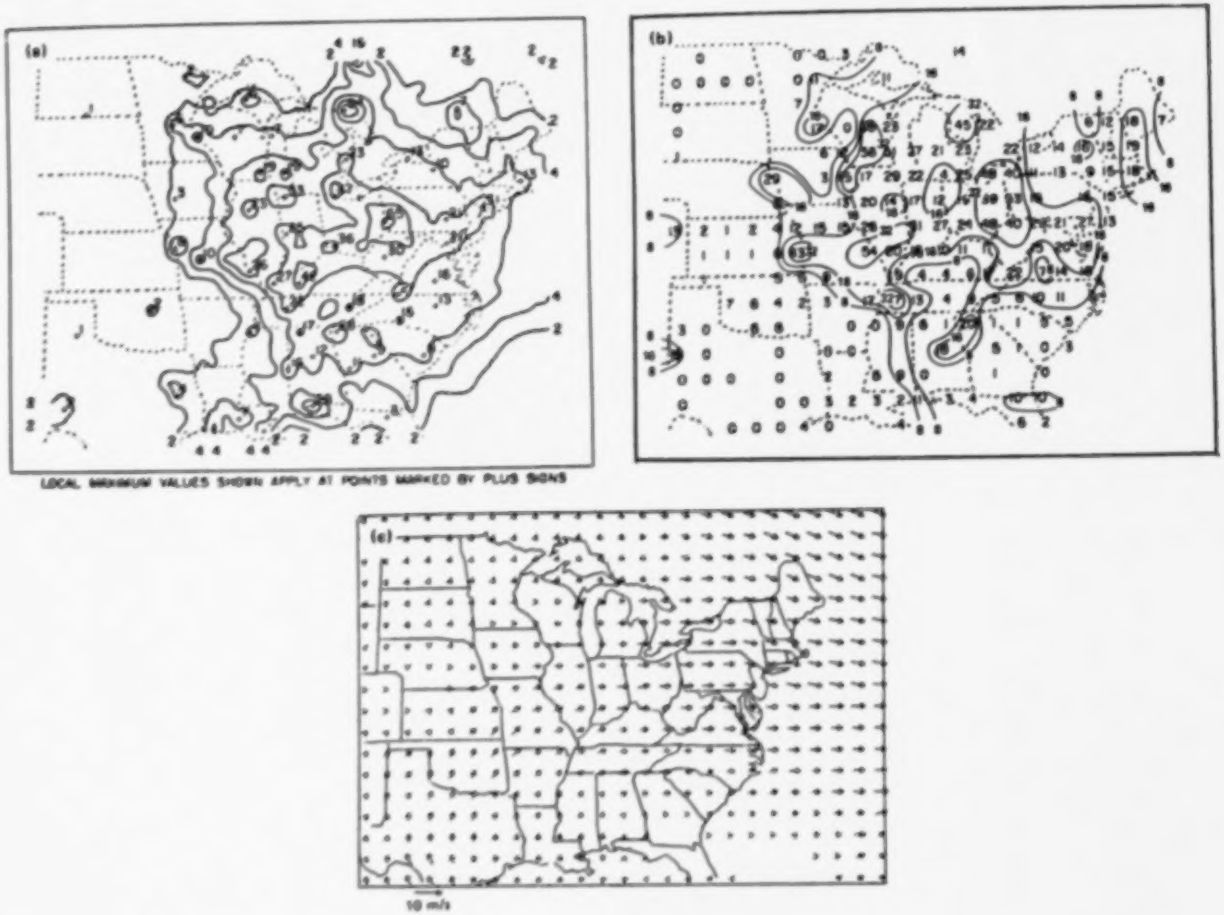
Figure 26. $SO_2$ concentrations ($\mu g/m^3$) for April 1975.
(a) calculated, (b) measured, (c) mean monthly transport winds.



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

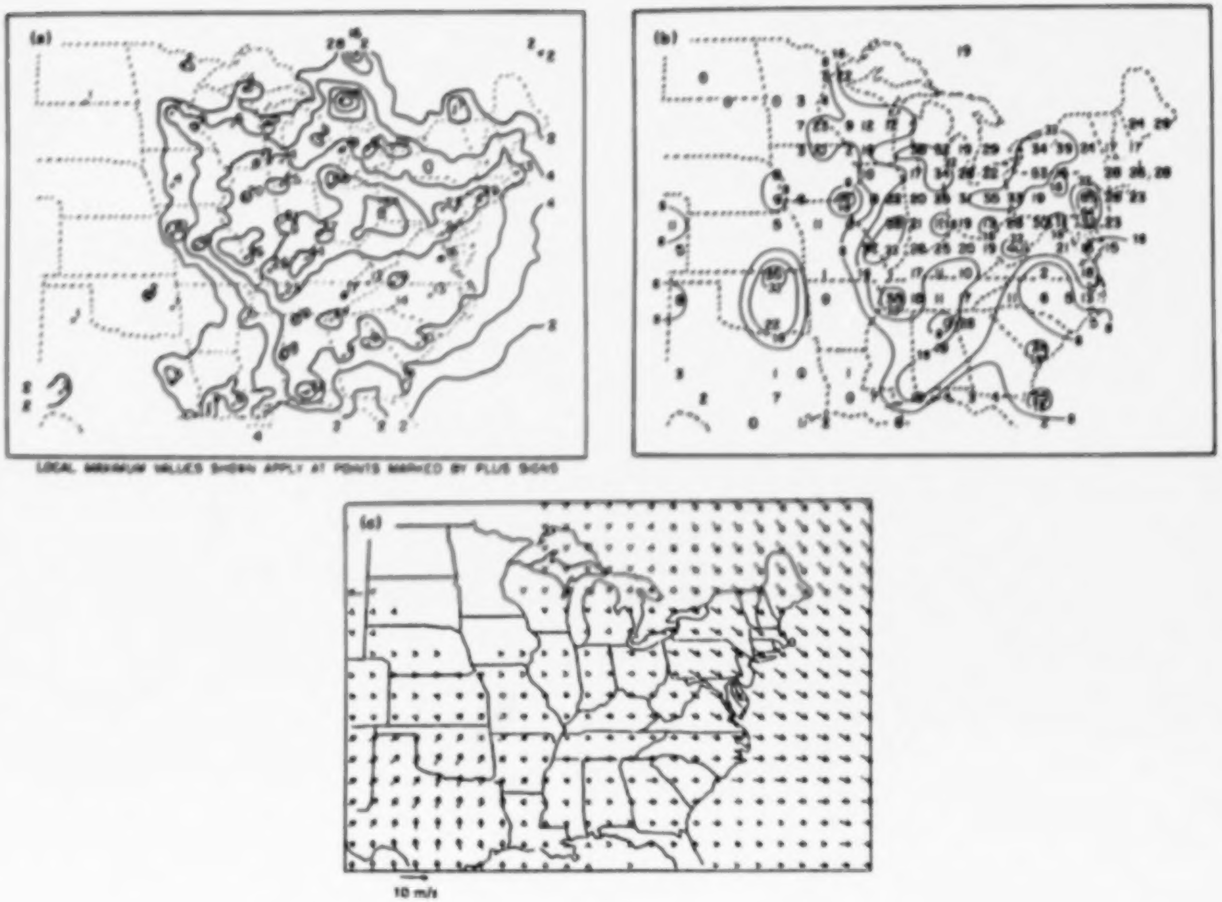
Figure 27. $SO_2$ concentrations ($\mu g/m^3$) for April 1976.

(a) calculated, (b) measured, (c) mean monthly transport winds.



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

Figure 28. $SO_2$ concentrations (μg/m$^3$) for April 1977.
(a) calculated, (b) measured, (c) mean monthly transport winds.



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

Figure 29. $SO_2$ concentrations ($\mu g/m^3$) for April 1978.
(a) calculated, (b) measured, (c) mean monthly transport winds.

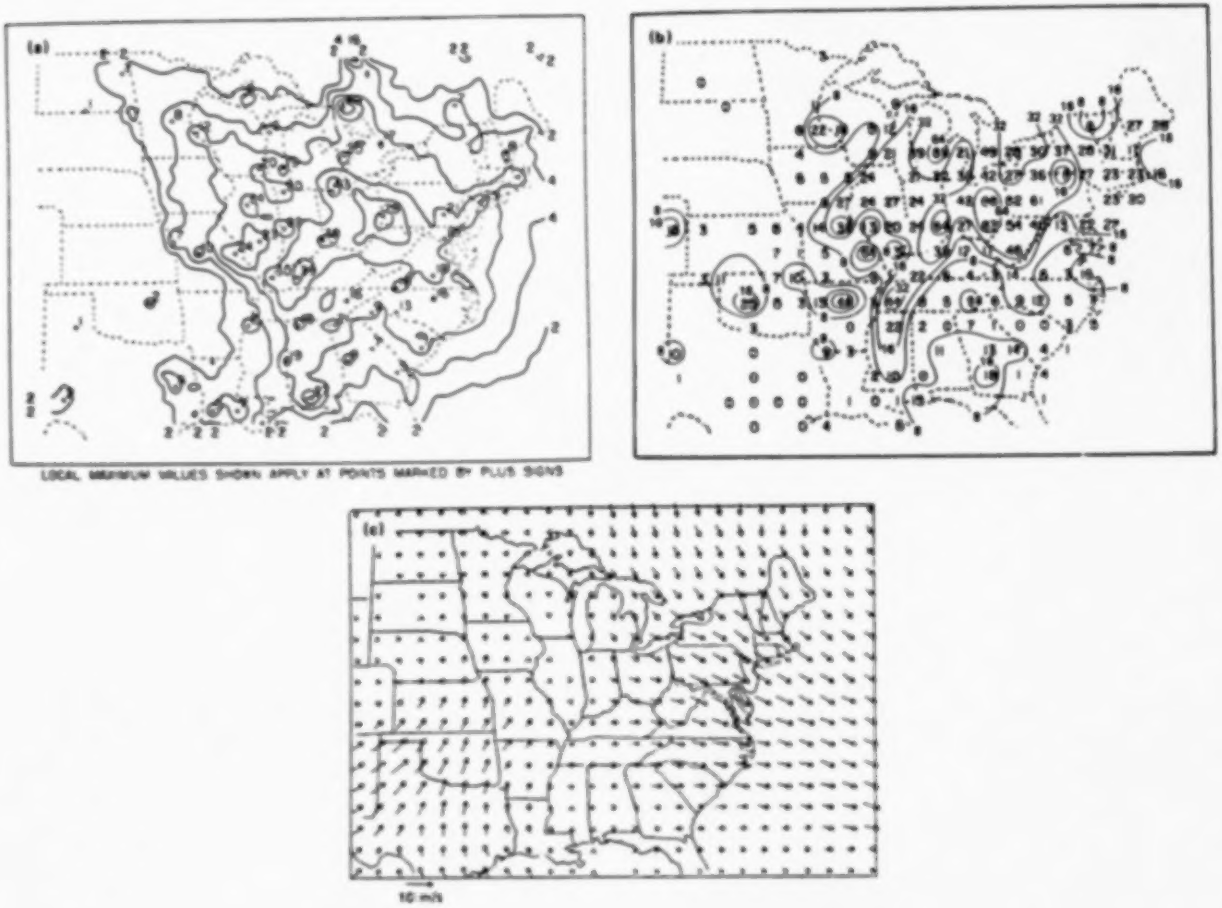

(a)
LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS
(b)
(c)
10 m/s

Figure 30. $SO_2$ concentrations ($\mu g/m^3$) for October 1975.
(a) calculated, (b) measured, (c) mean monthly transport winds.

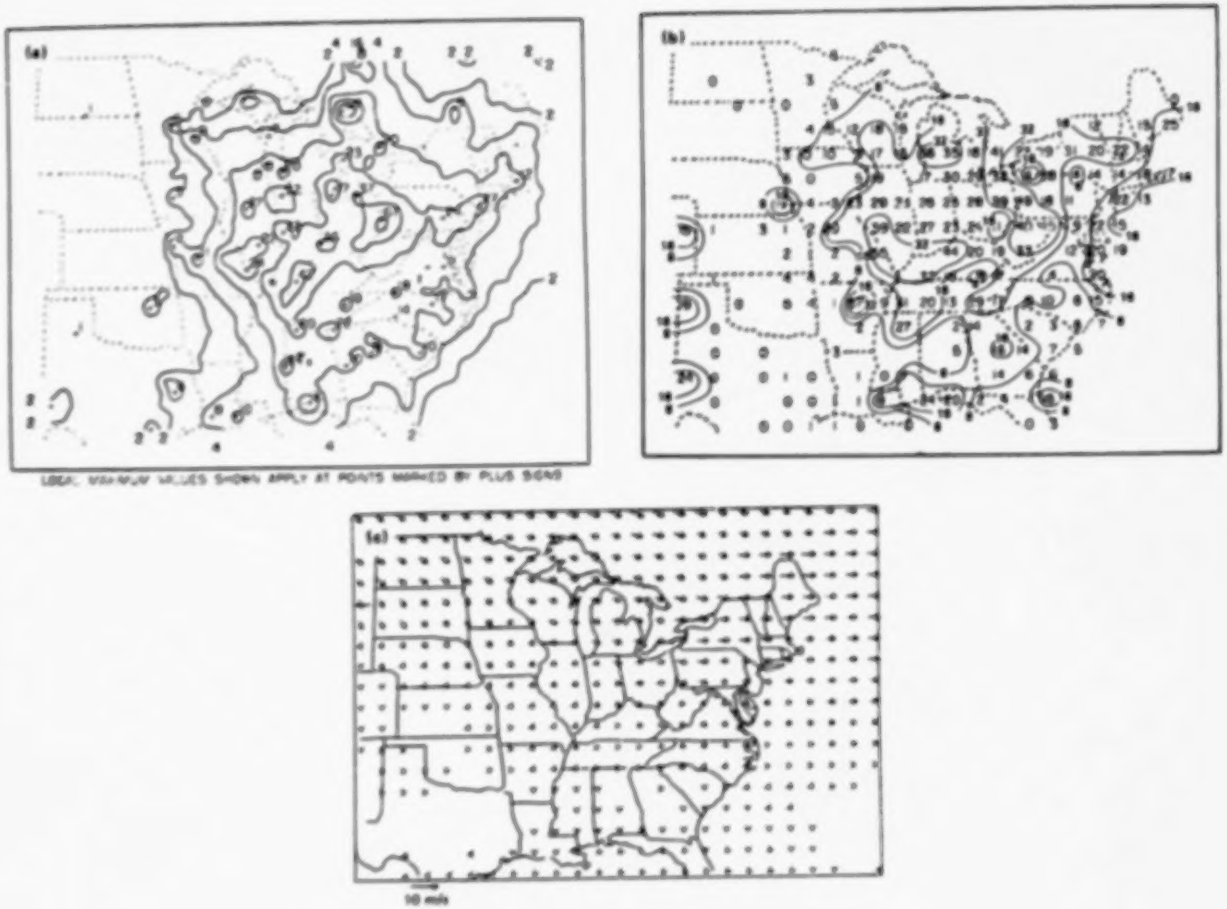

(a)
LEGEND: MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS
(b)
(c)
10 m/s

Figure 31. $SO_2$ concentrations (μg/m$^3$) for October 1976.
(a) calculated, (b) measured, (c) mean monthly transport winds.

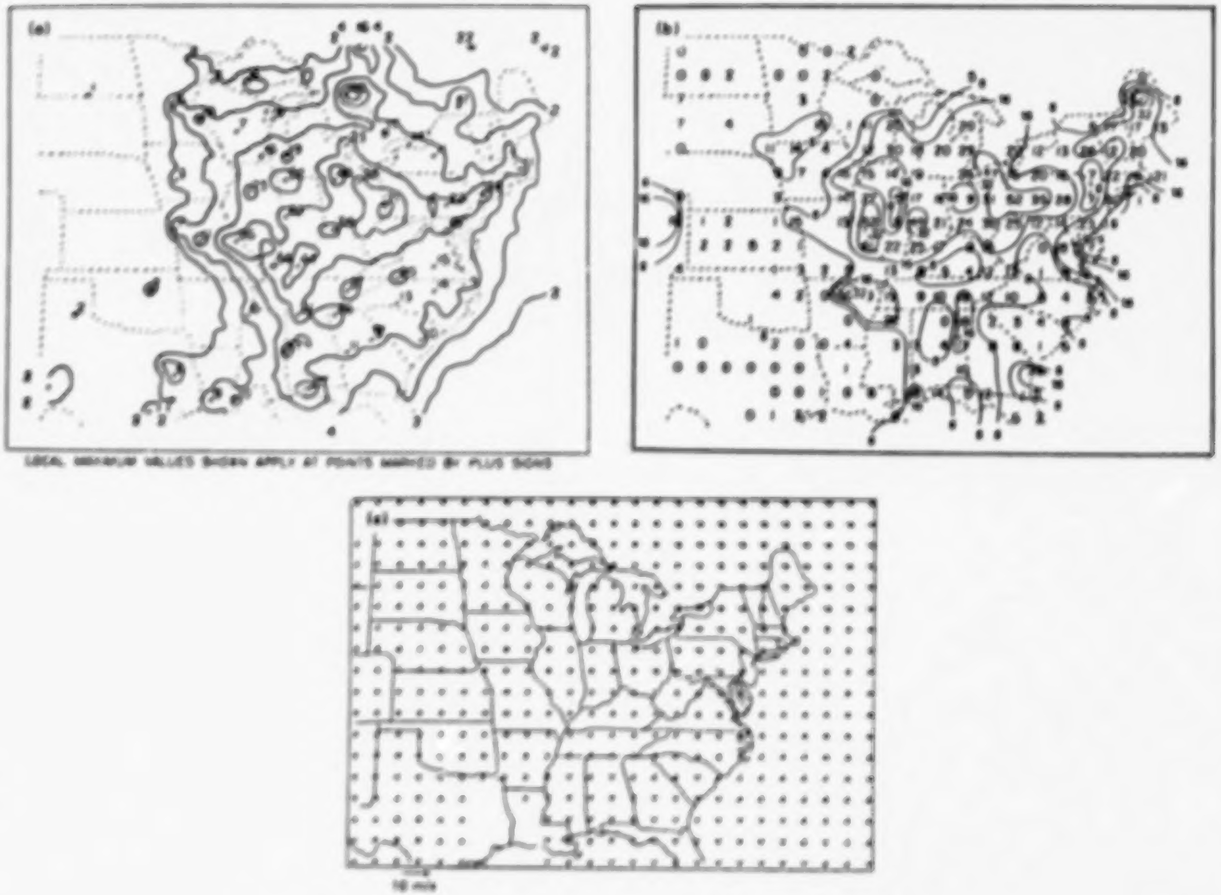

(a)
LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS
(b)
(c)
10 m/s

Figure 32. $SO_2$ concentrations ($\mu g/m^3$) for October 1977.
(a) calculated, (b) measured, (c) mean monthly transport winds.

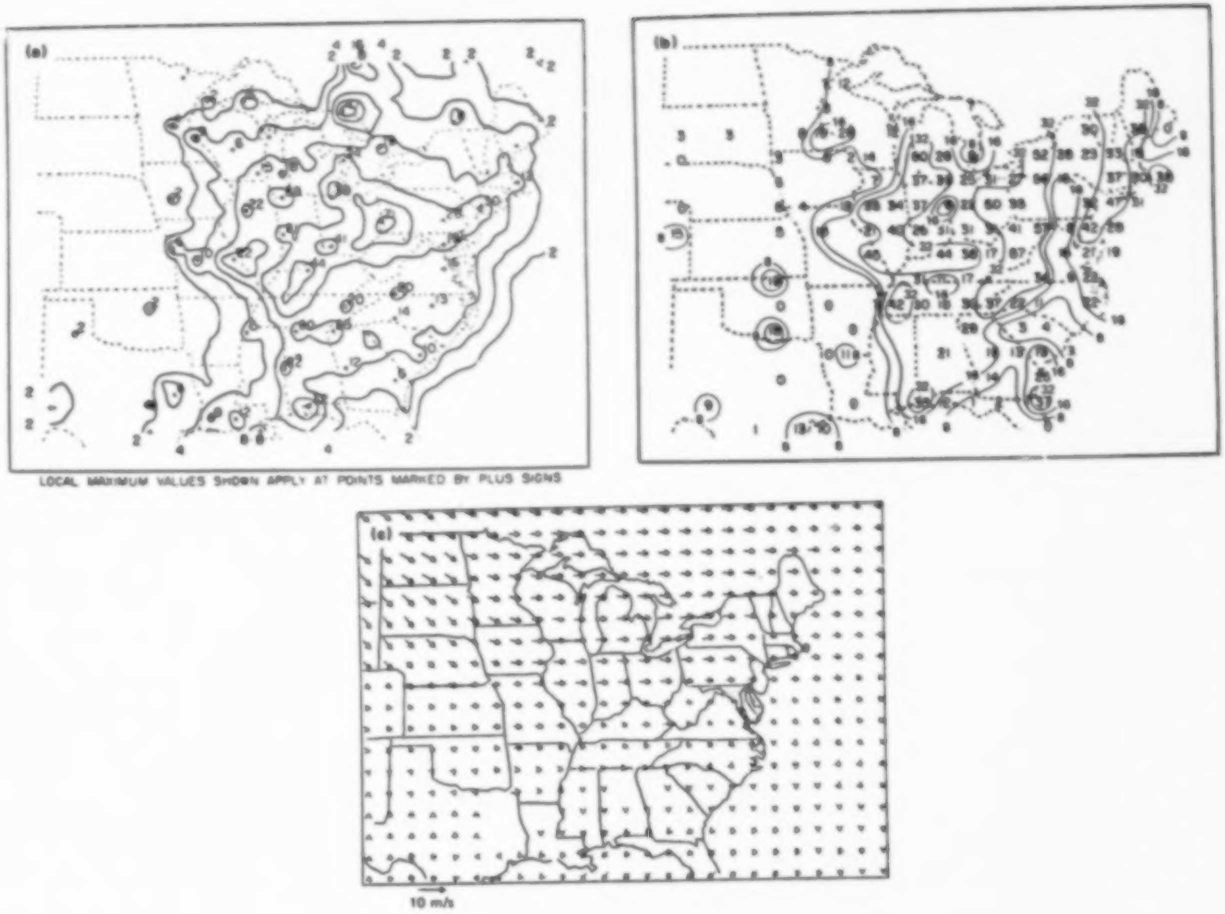

(a)
LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS
(b)
(c)
10 m/s

Figure 33. $SO_2$ concentrations ($\mu g/m^3$) for October 1978.
(a) calculated, (b) measured, (c) mean monthly transport winds.

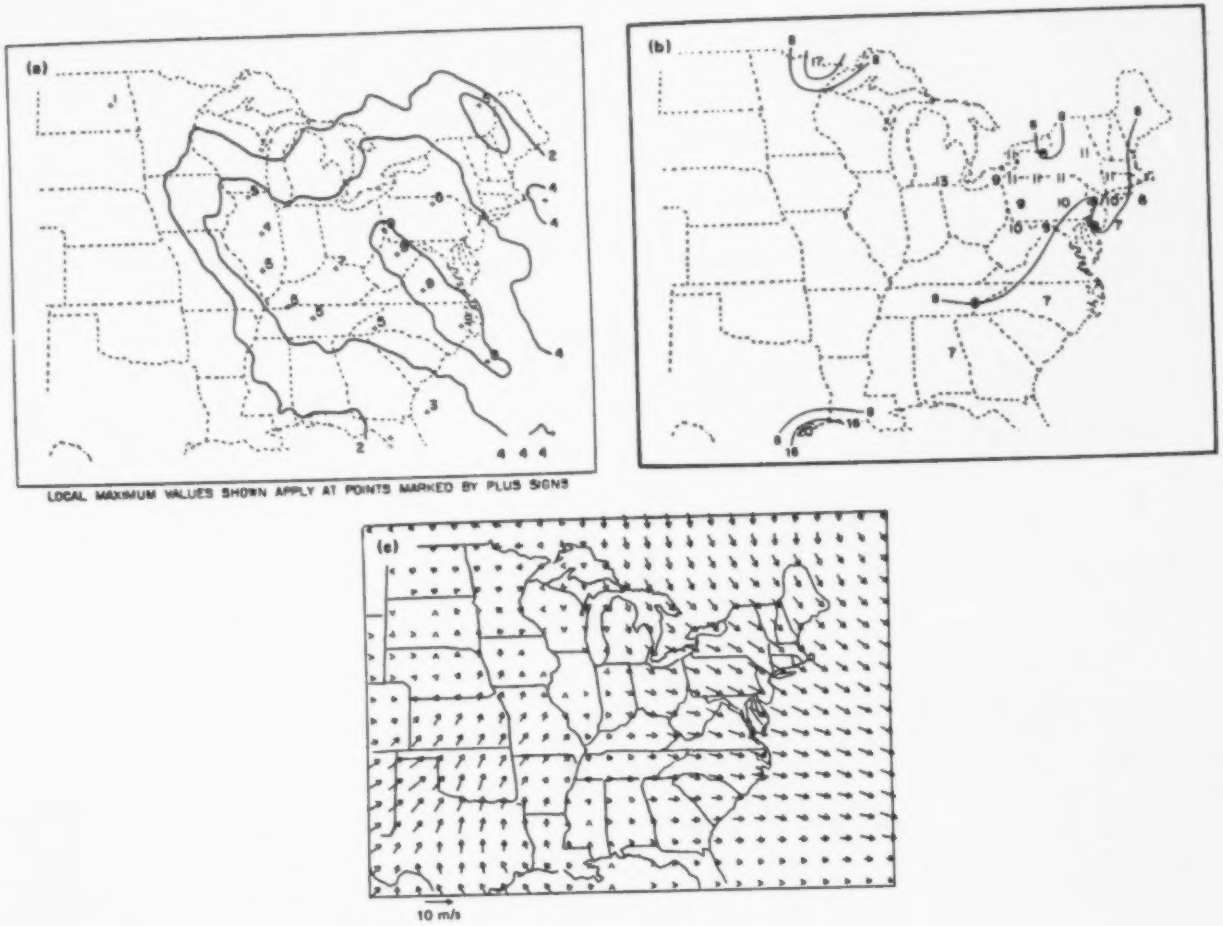
and October 1975 and the very low measured values over eastern Illinois in October 1977, nor the low values over the Appalachians that are depicted by the measurements, particularly in the October months of 1976, 1977, and 1978.

The $SO_4^=$ concentrations for the transitional months [part (a) of Figures 34 to 41] reflect more strongly the influence of the winds. The $SO_4^=$ concentration fields for April 1975, April 1978, and October 1975 all show the effect of wind confluence over the Virginias. In agreement with the flow patterns, the calculated $SO_4^=$ concentration patterns, particularly for the April months and October 1975, depict high values ($> 8\ \mu g/m^3$) east and south of the main emission centers and into the Atlantic. However, in October 1976, the high calculated $SO_4^=$ concentration values are over Ohio and Indiana and south into Alabama, and in October 1977 and 1978 they center over the middle eastern U.S. The measured $SO_4^=$ concentration data [part (b) of Figures 34 to 41] are generally very sparse, but those available do not appear to correspond too well with the calculated values. For example, during April 1977, the calculated $SO_4^=$ concentrations are quite high over the Virginias and the Carolinas, but this is not depicted by the observations. Such discrepancies possibly result because the ENAMAP-1 model does not consider terrain effects that would be of significant importance in the case of southeast transport of sulfur across the Appalachian mountains.

The $SO_4^=$ wet-deposition patterns for the transitional months [part (a) of Figures 42 to 49] reflect the role of precipitation in the model calculations. The precipitation patterns for the transitional months [part (b) of Figures 42 to 49] differ from one another considerably, but generally do not show much precipitation along the coastal areas. Only in April 1975 was there a large amount of precipitation along the southern Gulf Coast, and only in October of 1975 and 1976 was there a large amount along the East Coast. In two of the months, April 1976 and October 1978, there was very light rainfall over the normally wet southeastern United States.

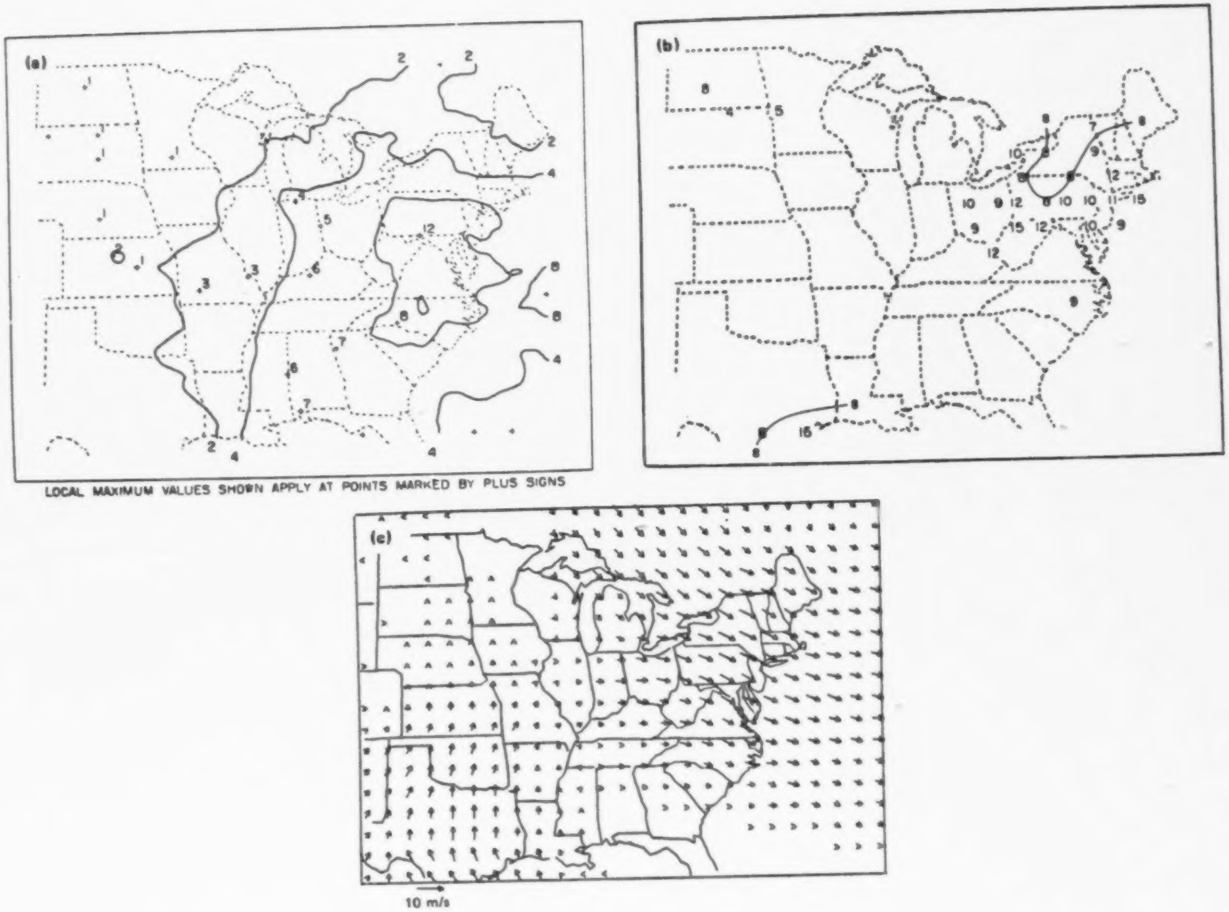
These variations in precipitation amounts are reflected in the $SO_4^=$ wet-deposition calculations. The high precipitation amounts over Iowa and Missouri in April 1978, over Alabama in October 1975, and over the East Coast in October 1976 and 1977 all correspond with relatively high $SO_4^=$ wet deposition calculations. The low precipitation amounts over the Southeast in April 1976 and October 1978, and over the west of the domain in October 1975, all correspond with relatively low $SO_4^=$ wet-deposition calculations. The effects of precipitation are very noticable for some of these transitional months, resulting in significant differences between the patterns of the $SO_4^=$ concentrations and wet depositions. For example, in October 1978, high $SO_4^=$ concentrations were calculated over the central eastern U.S., whereas high $SO_4^=$ wet depositions were calculated over the Ohio-Pennsylvania-New York area. (Low $SO_4^=$ wet depositions were calculated over much of the central eastern U.S. because of light rain.) Throughout these transitional months, high $SO_4^=$ wet depositions are depicted south of the Great Lakes and over the northeastern U.S. In the October months, the high $SO_4^=$ wet depositions tend to extend down into Alabama, and (in October 1977) into the Great Plains states.

Tables 4 and 5 provide an indication of the year to year changes for the transitional months. For example, they show that Region VI-East (Texas) produced 81.6 percent of the total sulfur deposited (33.5 ktons) within its area in April 1978; but only 54.4 percent of that deposited (55.3 ktons) in October 1976.



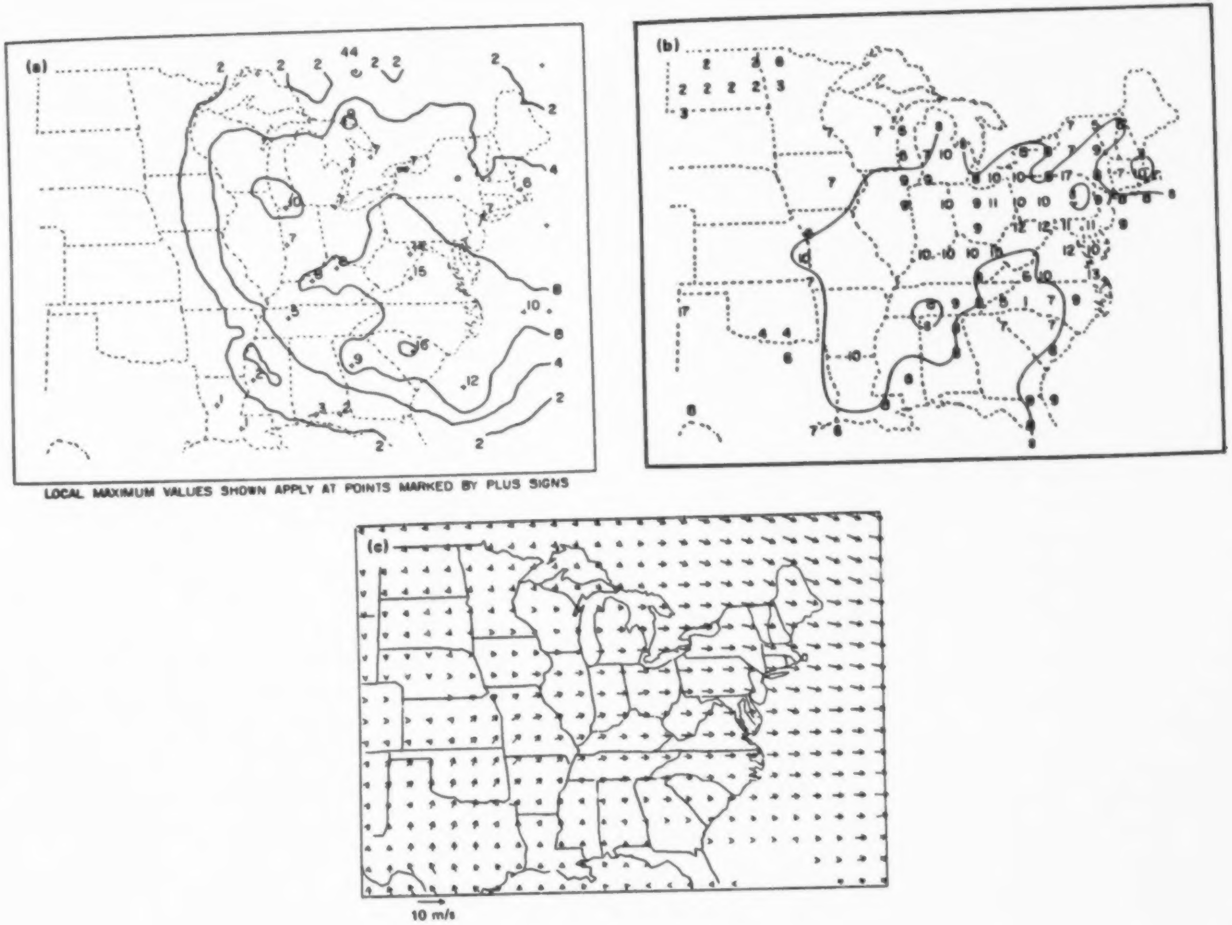
LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

Figure 34. $SO_4^=$ concentrations ($\mu g/m^3$) for April 1975.
(a) calculated, (b) measured, (c) mean monthly transport winds.



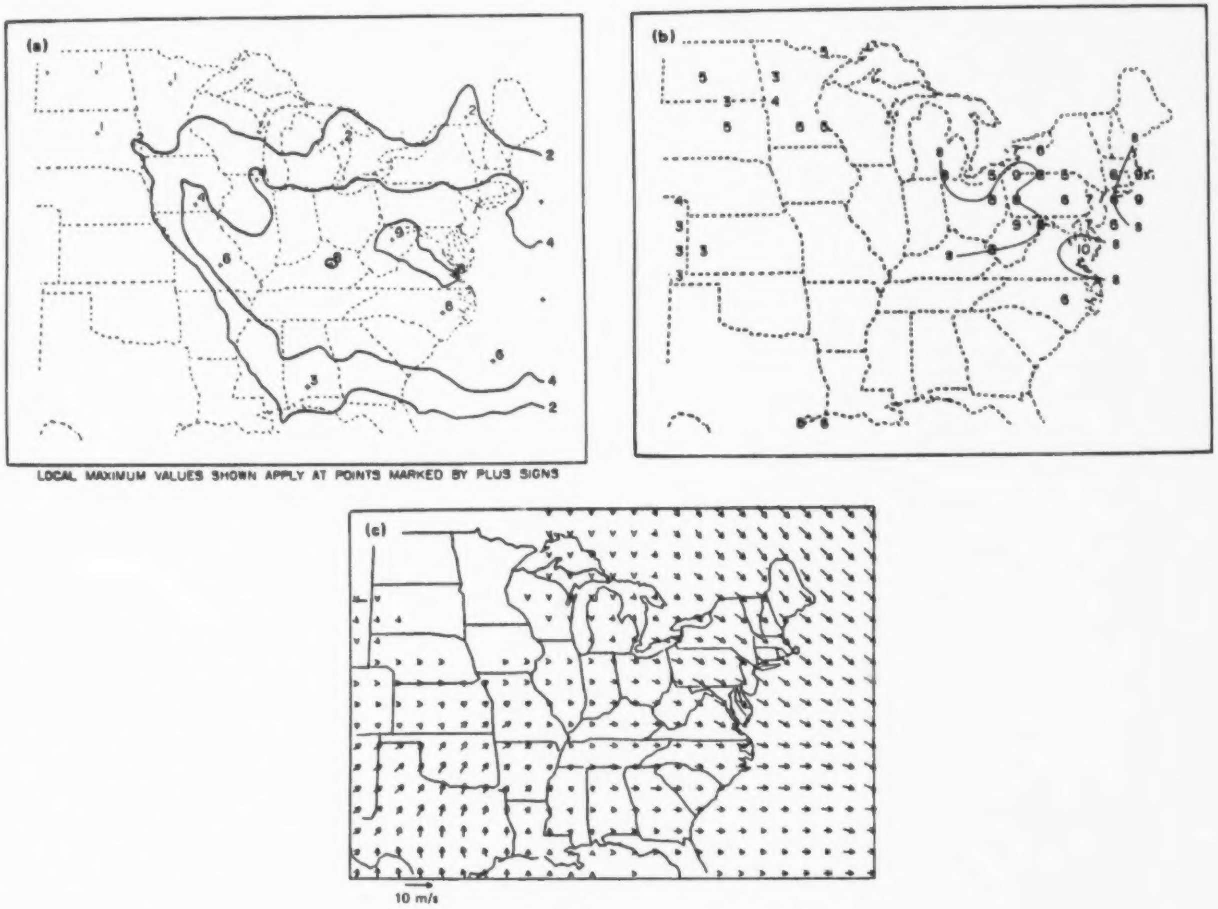
LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

Figure 35. $SO_4^=$ concentrations ($\mu g/m^3$) for April 1976.
(a) calculated, (b) measured, (c) mean monthly transport winds.



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

Figure 36. $SO_4^=$ concentrations ($\mu g/m^3$) for April 1977.
(a) calculated, (b) measured, (c) mean monthly transport winds.



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

Figure 37. $SO_4^=$ concentrations ($\mu g/m^3$) for April 1978.
(a) calculated, (b) measured, (c) mean monthly transport winds.

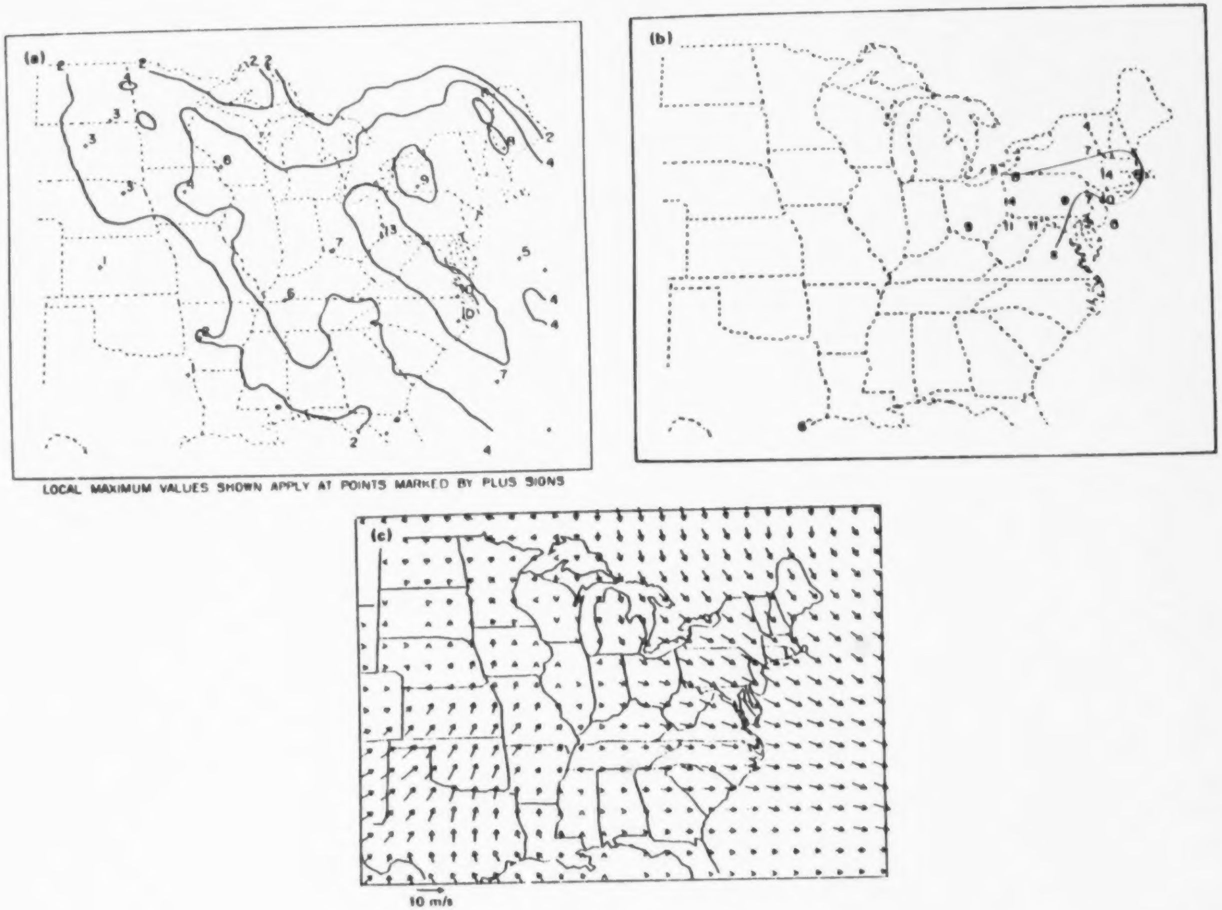

(a)
(b)
(c)
LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS
10 m/s

Figure 38. $SO_4$ concentrations ($\mu g/m^3$) for October 1975.
(a) calculated, (b) measured, (c) mean monthly transport winds.

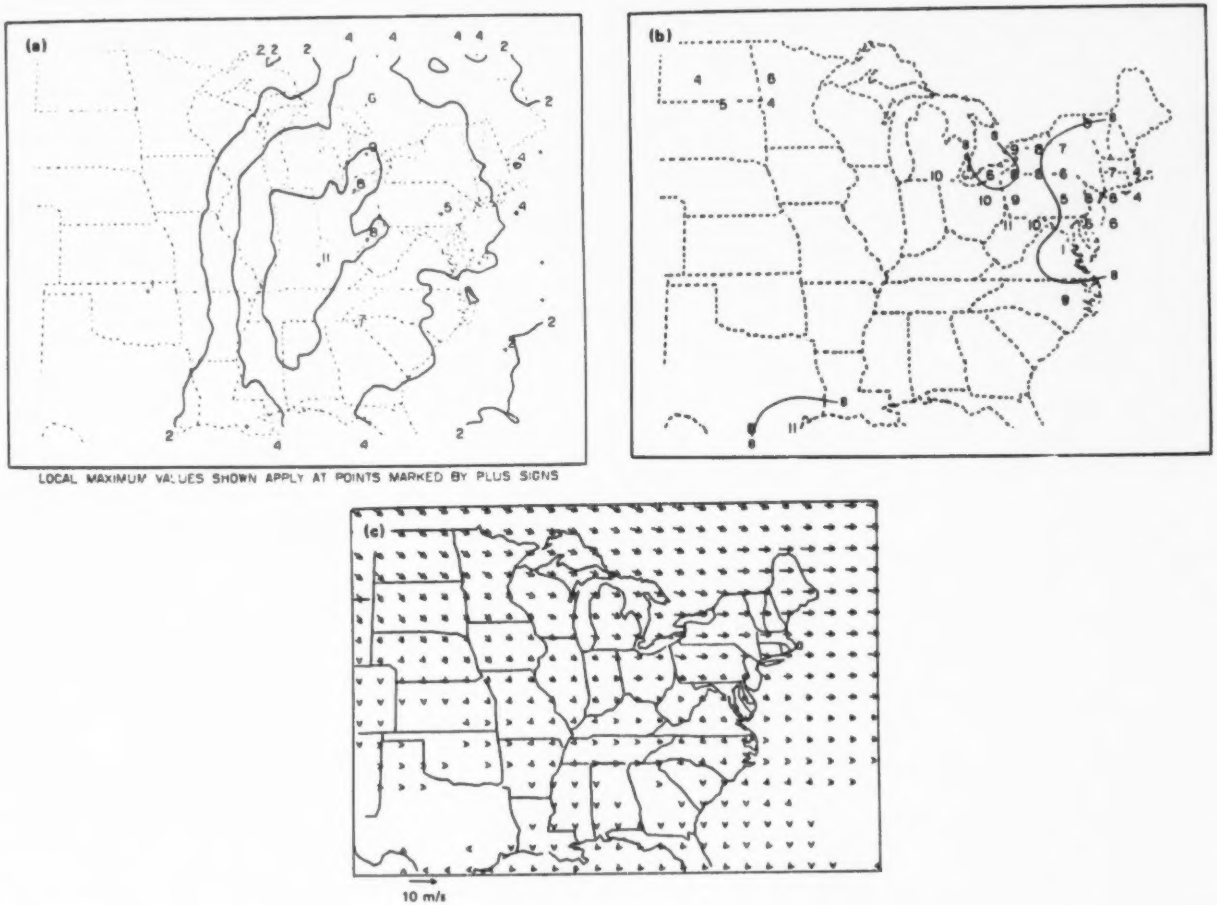
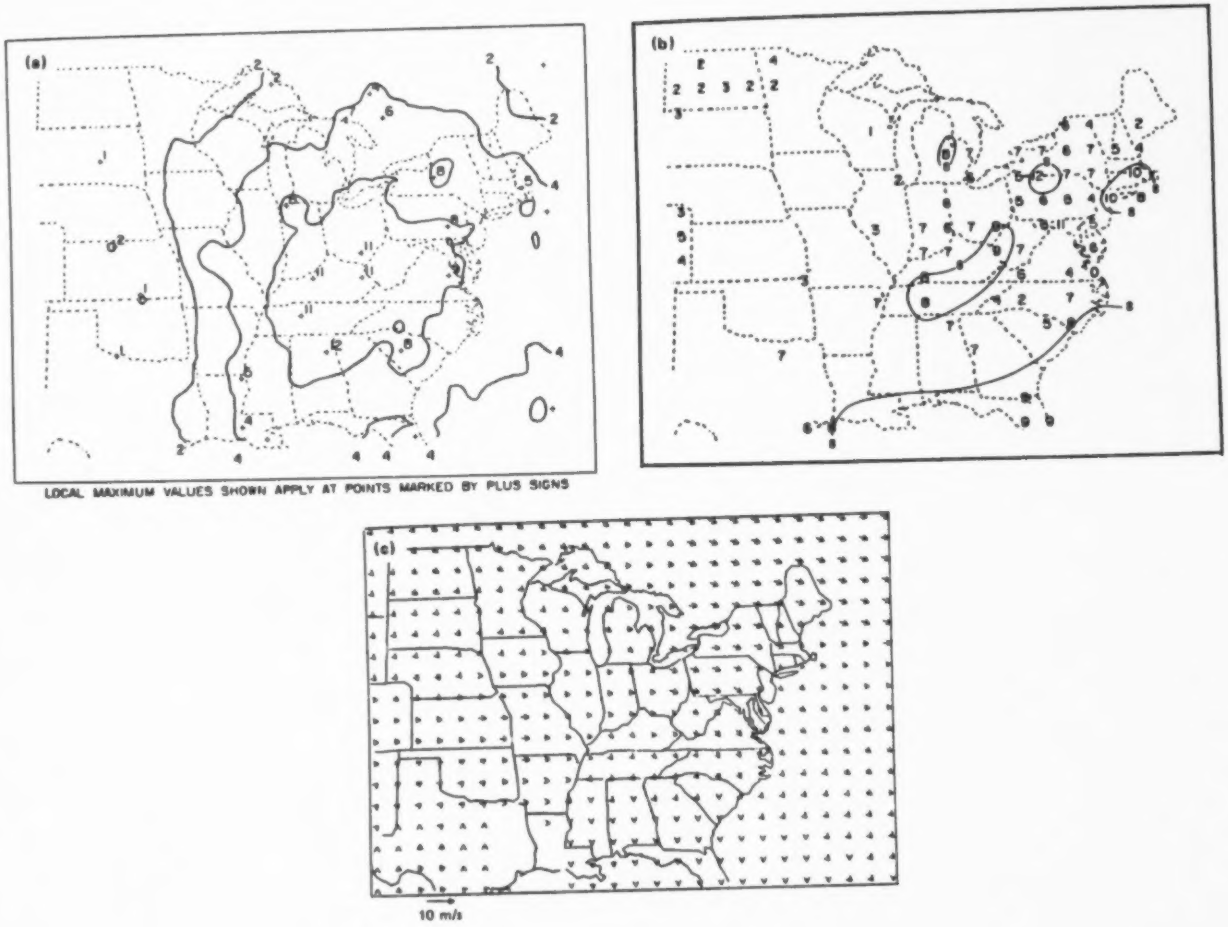

(a)
(b)
(c)
LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS
10 m/s

Figure 39. $SO_4^=$ concentrations ($\mu g/m^3$) for October 1976.

(a) calculated, (b) measured, (c) mean monthly transport winds.



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

Figure 40. $SO_4^=$ concentrations ($\mu g/m^3$) for October 1977.
(a) calculated, (b) measured, (c) mean monthly transport winds.

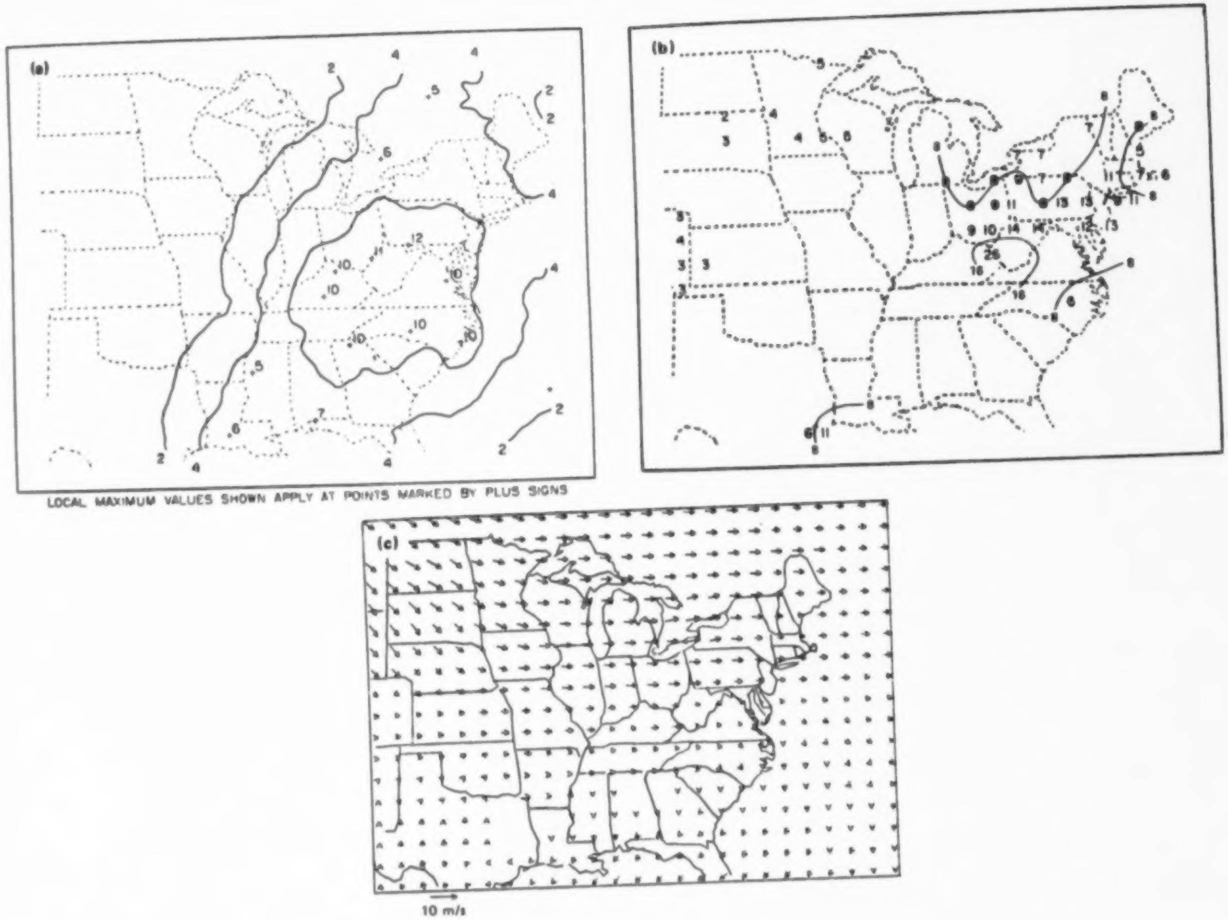
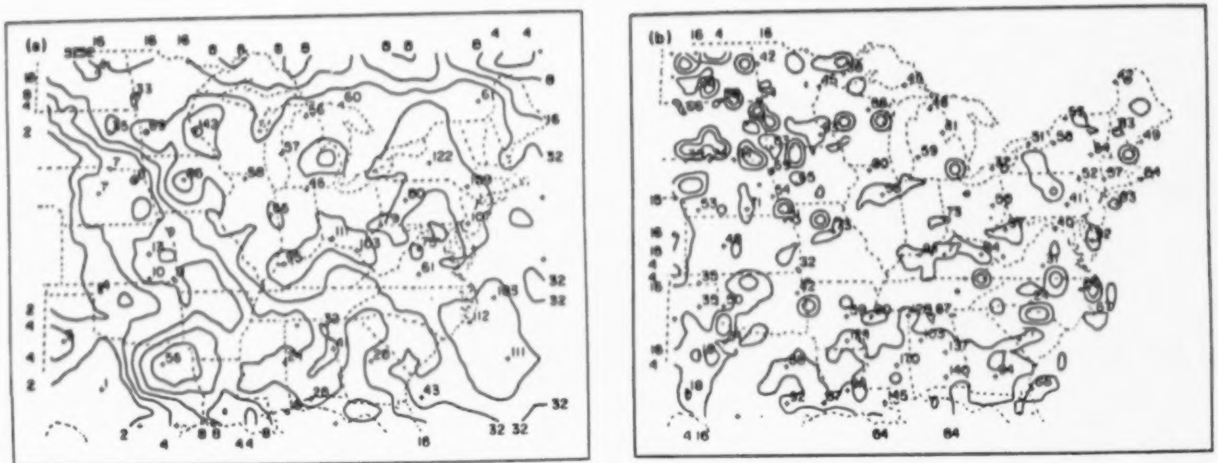

(a)
(b)
(c)
LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS
10 m/s

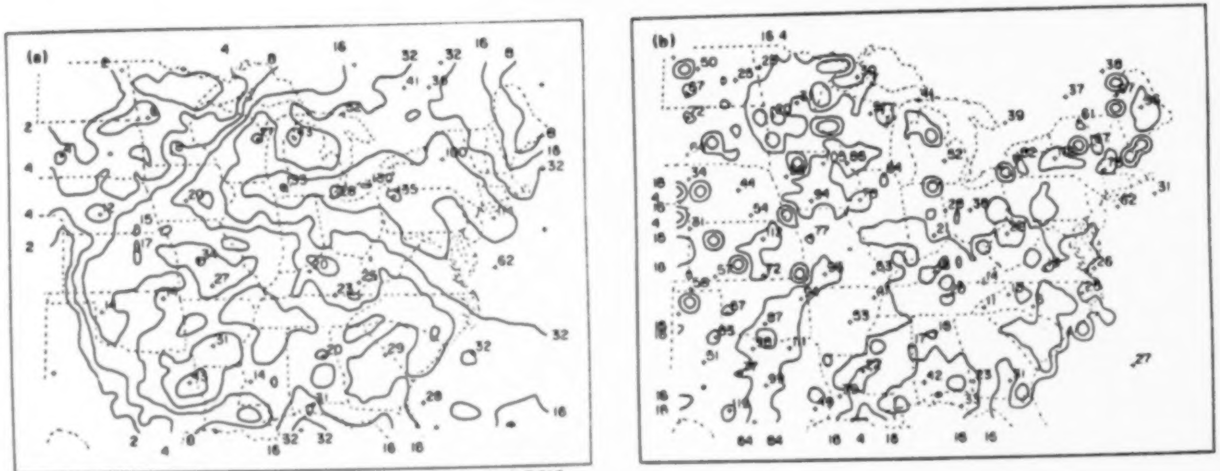
Figure 41. $SO_4^=$ concentrations ($\mu g/m^3$) for October 1978.
(a) calculated, (b) measured, (c) mean monthly transport winds.



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

Figure 42. $SO_4^=$ wet depositions for April 1975.

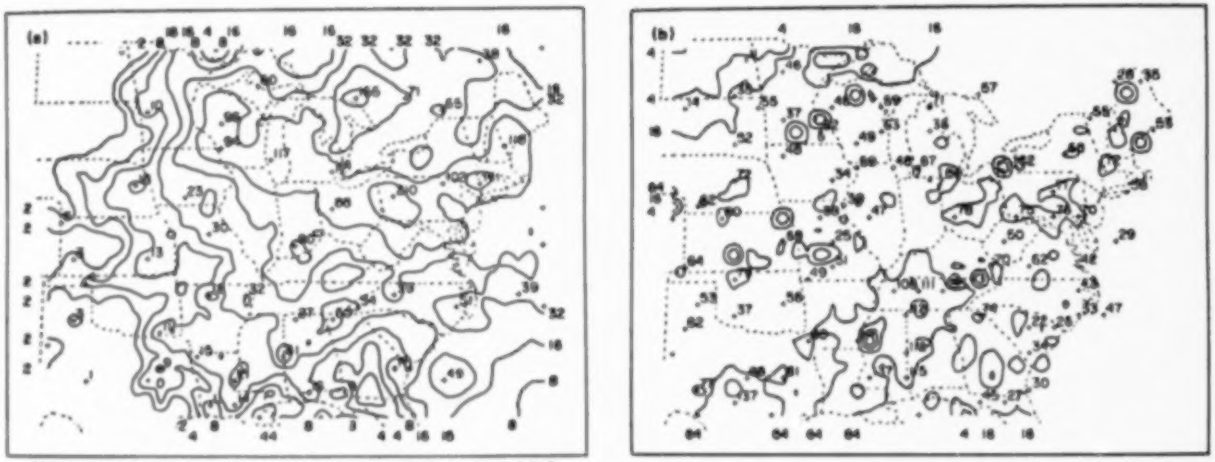
(a) calculated $SO_4^=$ wet depositions ($mg/m^2$), (b) precipitation (mm/month).



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

Figure 43. $SO_4^=$ wet depositions for April 1976.

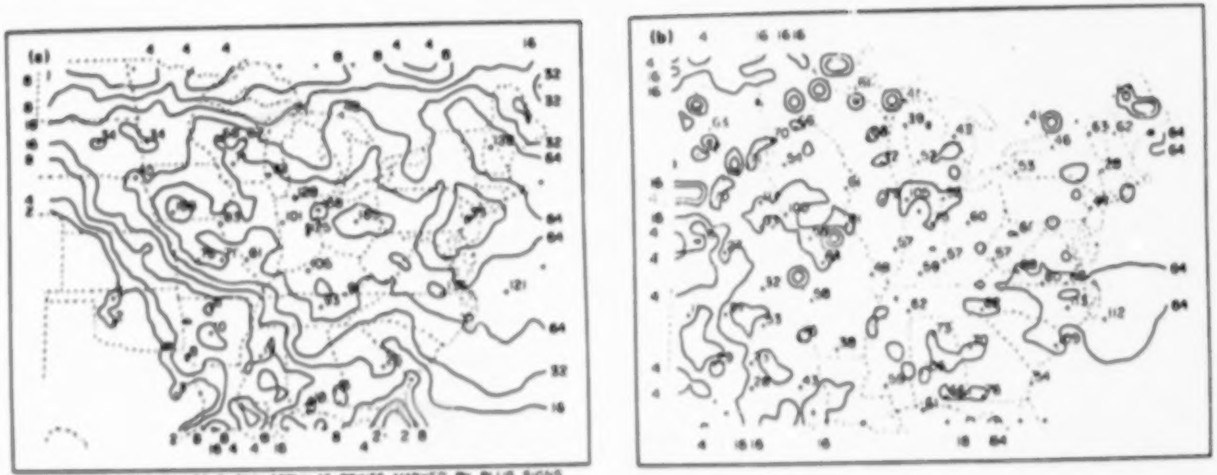
(a) calculated $SO_4^=$ wet depositions ($mg/m^2$), (b) precipitation (mm/month).



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

Figure 44. $SO_4^=$ wet depositions for April 1977.

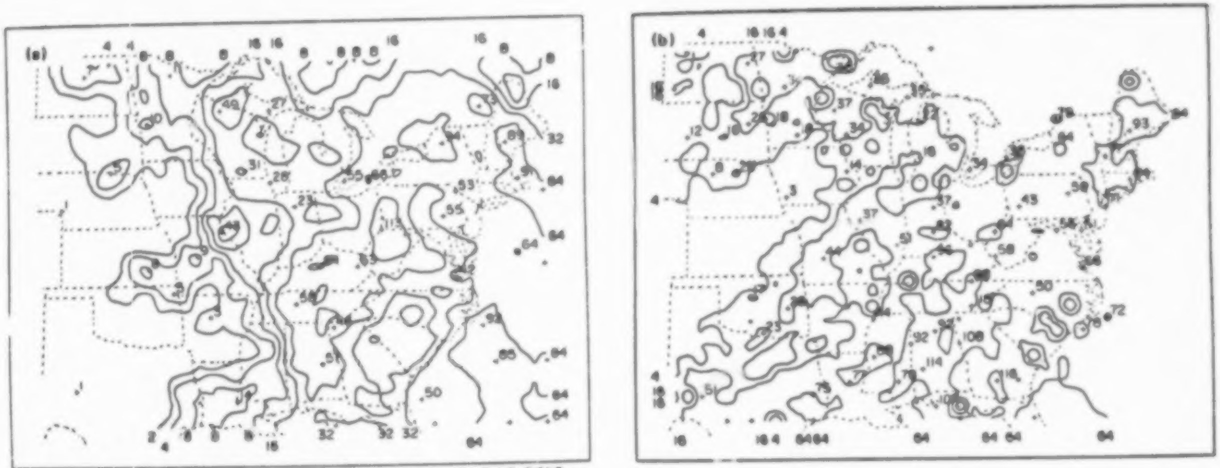
(a) calculated $SO_4^=$ wet depositions ($mg/m^2$), (b) precipitation (mm/month).



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

Figure 45. $SO_4^=$ wet depositions for April 1978.

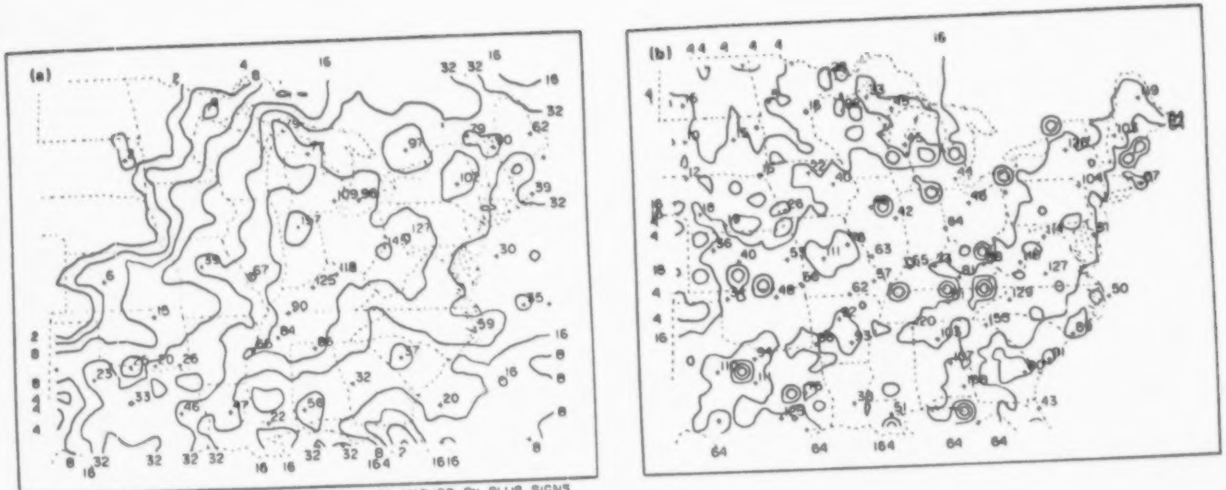
(a) calculated $SO_4^=$ wet depositions ($mg/m^2$), (b) precipitation (mm/month).



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

Figure 46. $SO_4^=$ wet depositions for October 1975.

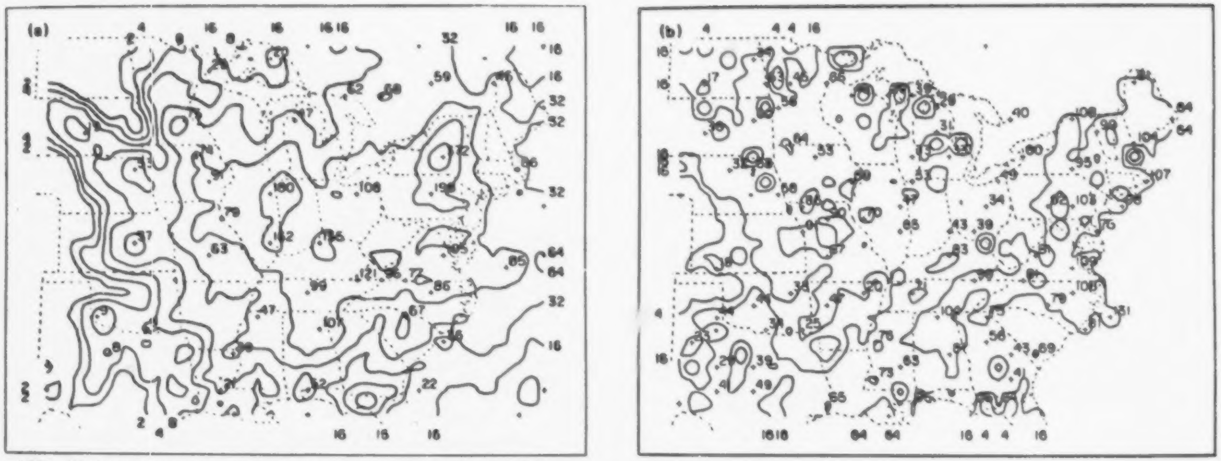
(a) calculated $SO_4^=$ wet depositions ($mg/m^2$), (b) precipitation (mm/month).



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

Figure 47. $SO_4^=$ wet depositions for October 1976.

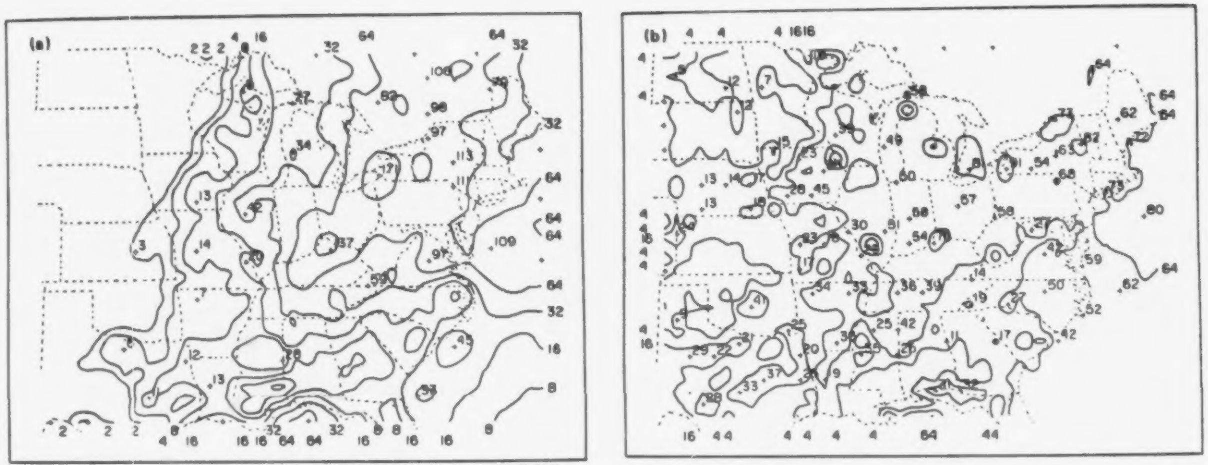
(a) calculated $SO_4^=$ wet depositions ($mg/m^2$), (b) precipitation (mm/month).



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

Figure 48. $SO_4^=$ wet depositions for October 1977.

(a) calculated $SO_4^=$ wet depositions ($mg/m^2$), (b) precipitation (mm/month).



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

Figure 49. $SO_4^=$ wet depositions for October 1978.

(a) calculated $SO_4^=$ wet depositions ($mg/m^2$), (b) precipitation (mm/month).

## TABLE 4. CALCULATED INTERREGIONAL EXCHANGES OF SULFUR FOR APRIL 1975, 1976, 1977, 1978*

### (a) APRIL 1975

TOTAL CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS (kilotons)

| | EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | VIII-NORTH | .9 | .0 | .0 | .1 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 2 | V-NORTH | 2.9 | 53.1 | 11.4 | 5.2 | .0 | .5 | 21.8 | .7 | 4.3 | 5.3 | 1.3 | .5 | .4 |
| 3 | S ONTARIO | .0 | 6.8 | 60.5 | .1 | 0.0 | .1 | 6.9 | .2 | 2.2 | 8.4 | 3.4 | .9 | 1.9 |
| 4 | VII | 3.1 | 5.1 | .4 | 30.0 | .0 | 2.3 | 8.6 | .7 | 1.0 | .2 | .1 | .0 | .0 |
| 5 | VIII-SOUTH | 0.0 | 0.0 | 0.0 | .0 | .0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 | VI-EAST | .9 | .8 | .3 | 4.8 | .1 | 28.8 | 1.3 | 3.2 | 1.2 | .1 | .1 | .0 | .1 |
| 7 | V-SOUTH | 3.1 | 19.3 | 10.5 | 23.2 | .0 | 2.5 | 118.5 | 6.3 | 33.6 | 30.9 | 4.3 | 1.3 | 1.3 |
| 8 | IV-SOUTH | .0 | .1 | .3 | .3 | .0 | 3.1 | 2.1 | 67.2 | 23.0 | 5.0 | .7 | .4 | .2 |
| 9 | IV-NORTH | .2 | 1.2 | 3.5 | 2.0 | .0 | 1.7 | 19.6 | 9.6 | 63.4 | 7.9 | 1.2 | .6 | .5 |
| 10 | III | 0.0 | .1 | 5.5 | 0.0 | 0.0 | 0.0 | 12.4 | .1 | 13.2 | 95.0 | 9.9 | 2.5 | 2.3 |
| 11 | II | 0.0 | .0 | 3.9 | 0.0 | 0.0 | 0.0 | .0 | 0.0 | .0 | 3.8 | 13.7 | 2.9 | .9 |
| 12 | I | 0.0 | 0.0 | .1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .0 | .3 | 6.5 | 13.0 | 1.2 |
| 13 | S. QUEBEC | .0 | .1 | 14.8 | .0 | 0.0 | .0 | .1 | .0 | .0 | .5 | 1.3 | 2.6 | 10.0 |
| | TOTAL (KTON S) | 11.2 | 86.6 | 111.2 | 65.7 | .1 | 39.0 | 191.2 | 88.0 | 142.0 | 157.5 | 42.5 | 25.0 | 18.7 |

PERCENT CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS

| | EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | VIII-NORTH | 7.9 | .0 | .0 | .1 | .2 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 2 | V-NORTH | 25.9 | 61.3 | 10.2 | 7.9 | 2.3 | 1.3 | 11.4 | .8 | 3.0 | 3.4 | 3.0 | 2.0 | 2.0 |
| 3 | S. ONTARIO | .3 | 7.8 | 54.4 | .2 | 0.0 | .3 | 3.6 | .3 | 1.5 | 5.3 | 8.0 | 3.7 | 9.9 |
| 4 | VII | 28.0 | 5.9 | .3 | 45.6 | 2.5 | 6.0 | 4.5 | .8 | .7 | .1 | .3 | .1 | .2 |
| 5 | VIII-SOUTH | 0.0 | 0.0 | 0.0 | .0 | 2.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 | VI-EAST | 8.2 | .9 | .3 | 7.3 | 77.7 | 73.9 | .7 | 3.7 | .9 | .1 | .1 | .0 | .3 |
| 7 | V-SOUTH | 28.0 | 22.3 | 9.5 | 35.4 | 11.9 | 6.3 | 62.0 | 7.1 | 23.7 | 19.6 | 10.2 | 5.4 | 7.2 |
| 8 | IV-SOUTH | .1 | .1 | .3 | .5 | 1.5 | 7.8 | 1.1 | 76.3 | 16.2 | 3.2 | 1.7 | 1.7 | 1.1 |
| 9 | IV-NORTH | 1.7 | 1.4 | 3.1 | 3.0 | 1.4 | 4.3 | 10.2 | 11.0 | 44.7 | 5.0 | 2.9 | 2.3 | 2.5 |
| 10 | III | 0.0 | .1 | 4.9 | 0.0 | 0.0 | 0.0 | 6.5 | .1 | 9.3 | 60.3 | 23.3 | 10.1 | 12.3 |
| 11 | II | 0.0 | .0 | 3.5 | 0.0 | 0.0 | 0.0 | .0 | 0.0 | .0 | 2.4 | 32.2 | 11.8 | 4.8 |
| 12 | I | 0.0 | 0.0 | .1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .0 | .2 | 15.3 | 52.2 | 6.4 |
| 13 | S. QUEBEC | .0 | .1 | 13.3 | .0 | 0.0 | .0 | .0 | .0 | .0 | .3 | 3.0 | 10.6 | 53.2 |

## TABLE 4 (continued)

### (b) APRIL 1976

TOTAL CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS (kilotons)

| EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 VIII-NORTH | .8 | .1 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 0.0 |
| 2 V-NORTH | 1.5 | 49.2 | 18.5 | 5.9 | .0 | .5 | 18.4 | 1.0 | 3.0 | 6.3 | 2.0 | .5 | .8 |
| 3 S. ONTARIO | .0 | 5.4 | 60.8 | .0 | .0 | .0 | 4.2 | .4 | 1.4 | 8.8 | 5.2 | 1.3 | 3.9 |
| 4 VII | .8 | 4.2 | 1.4 | 30.4 | .0 | 1.5 | 8.6 | .6 | 2.3 | .6 | .1 | .0 | .2 |
| 5 VIII-SOUTH | 0.0 | 0.0 | 0.0 | .0 | .0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 VI-EAST | .1 | .6 | .3 | 4.0 | .3 | 30.3 | .7 | 3.3 | .4 | .1 | .0 | .0 | .0 |
| 7 V-SOUTH | .7 | 15.2 | 15.2 | 18.0 | .0 | 5.8 | 108.6 | 6.2 | 32.3 | 40.3 | 5.6 | 1.2 | 1.6 |
| 8 IV-SOUTH | 0.0 | 1.2 | 1.8 | .2 | 0.0 | 4.2 | 3.9 | 64.3 | 18.3 | 3.3 | .6 | .2 | .4 |
| 9 IV-NORTH | .1 | 2.5 | 3.2 | .7 | .0 | 4.4 | 15.0 | 10.9 | 57.2 | 11.1 | 1.5 | .4 | .4 |
| 10 III | 0.0 | .1 | 3.4 | 0.0 | 0.0 | .0 | 8.4 | 1.9 | 12.5 | 97.4 | 10.5 | 2.3 | .5 |
| 11 II | 0.0 | .0 | 3.4 | 0.0 | 0.0 | 0.0 | .0 | .0 | .1 | 2.4 | 14.7 | 3.3 | .6 |
| 12 I | 0.0 | 0.0 | .1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .0 | .1 | 5.6 | 11.9 | 1.8 |
| 13 S. QUEBEC | 0.0 | .0 | 12.8 | .0 | 0.0 | .0 | .0 | .0 | .0 | .4 | 1.3 | 2.8 | 11.5 |
| TOTAL (KTON S) | 4.0 | 78.4 | 121.1 | 59.2 | .4 | 46.7 | 167.9 | 88.5 | 127.6 | 170.8 | 47.0 | 24.0 | 21.7 |

PERCENT CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS

| EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 VIII-NORTH | 19.5 | .1 | .0 | .1 | .5 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 0.0 |
| 2 V-NORTH | 37.5 | 62.7 | 15.3 | 10.0 | 2.4 | 1.1 | 11.0 | 1.2 | 2.4 | 3.7 | 4.2 | 2.2 | 3.7 |
| 3 S. ONTARIO | .0 | 6.9 | 50.2 | .0 | .4 | .0 | 2.5 | .5 | 1.1 | 5.2 | 11.2 | 5.5 | 18.1 |
| 4 VII | 19.7 | 5.4 | 1.2 | 51.4 | 4.5 | 3.2 | 5.1 | .6 | 1.8 | .4 | .1 | .1 | .7 |
| 5 VIII-SOUTH | 0.0 | 0.0 | 0.0 | .0 | .5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 VI-EAST | 2.4 | .7 | .3 | 6.7 | 84.3 | 64.8 | .4 | 3.7 | .3 | .0 | .1 | .1 | .2 |
| 7 V-SOUTH | 18.7 | 19.4 | 12.6 | 30.3 | 4.5 | 12.5 | 64.7 | 7.0 | 25.3 | 23.6 | 11.9 | 5.1 | 7.4 |
| 8 IV-SOUTH | 0.0 | 1.6 | 1.5 | .3 | 0.0 | 9.0 | 2.3 | 72.6 | 14.4 | 1.9 | 1.2 | .7 | 1.7 |
| 9 IV-NORTH | 2.3 | 3.2 | 2.7 | 1.2 | 2.7 | 9.4 | 8.9 | 12.3 | 44.8 | 6.5 | 3.1 | 1.5 | 1.8 |
| 10 III | 0.0 | .1 | 2.8 | 0.0 | 0.0 | .0 | 5.0 | 2.1 | 9.8 | 57.0 | 22.4 | 9.4 | 2.4 |
| 11 II | 0.0 | .0 | 2.8 | 0.0 | 0.0 | 0.0 | .0 | .0 | .1 | 1.4 | 31.2 | 14.0 | 2.6 |
| 12 I | 0.0 | 0.0 | .1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .0 | .1 | 11.9 | 49.5 | 8.2 |
| 13 S. QUEBEC | 0.0 | .0 | 10.6 | .0 | 0.0 | .0 | .0 | .0 | .0 | .2 | 2.8 | 11.9 | 53.2 |

## TABLE 4 (continued)

### (c) APRIL 1977

TOTAL CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS (kilotons)

| EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 VIII-NORTH | .8 | .0 | .0 | .1 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 2 V-NORTH | .1 | 56.2 | 19.1 | 4.3 | .0 | .3 | 18.9 | .4 | 1.9 | 4.9 | 2.5 | 1.2 | 1.1 |
| 3 S. ONTARIO | .0 | 7.6 | 66.7 | .0 | 0.0 | .0 | 4.8 | .0 | .7 | 6.4 | 4.0 | 2.1 | 4.0 |
| 4 VII | .0 | 5.2 | 1.2 | 27.6 | .0 | 1.7 | 9.8 | .9 | 2.7 | 1.0 | .3 | .2 | .2 |
| 5 VIII-SOUTH | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 VI-EAST | .2 | .9 | .3 | 4.3 | .2 | 30.7 | .7 | 3.1 | .6 | .1 | .1 | .1 | .0 |
| 7 V-SOUTH | 0.0 | 22.7 | 12.2 | 11.3 | 0.0 | .6 | 129.4 | 3.4 | 31.8 | 38.3 | 3.4 | 1.5 | 1.3 |
| 8 IV-SOUTH | .1 | 2.2 | 1.2 | 3.0 | .0 | 3.7 | 3.8 | 70.2 | 21.4 | 3.0 | .3 | .3 | .1 |
| 9 IV-NORTH | .0 | 3.3 | 2.8 | 1.0 | 0.0 | .5 | 19.2 | 5.1 | 71.0 | 9.7 | .4 | .5 | .2 |
| 10 III | .0 | .4 | 5.7 | .0 | 0.0 | .0 | 13.3 | .2 | 12.4 | 108.2 | 9.9 | 3.6 | 1.8 |
| 11 II | 0.0 | .0 | 4.4 | 0.0 | 0.0 | 0.0 | .0 | 0.0 | .0 | 3.0 | 15.5 | 4.4 | 1.4 |
| 12 I | 0.0 | 0.0 | .1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .0 | .3 | 7.2 | 14.9 | 2.4 |
| 13 S. QUEBEC | 0.0 | .3 | 11.1 | 0.0 | 0.0 | 0.0 | .1 | 0.0 | .0 | .1 | .6 | 2.8 | 14.3 |
| TOTAL (KTON S) | 1.3 | 99.0 | 124.7 | 51.6 | .2 | 37.6 | 199.9 | 83.1 | 142.6 | 175.0 | 44.3 | 31.5 | 26.9 |

PERCENT CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS

| EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 VIII-NORTH | 64.4 | .0 | .0 | .3 | 10.3 | .1 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 2 V-NORTH | 9.5 | 56.8 | 15.4 | 8.3 | .1 | .7 | 9.5 | .4 | 1.3 | 2.8 | 5.7 | 3.7 | 4.0 |
| 3 S. ONTARIO | .2 | 7.7 | 53.5 | .0 | 0.0 | .0 | 2.4 | .0 | .5 | 3.7 | 9.0 | 6.6 | 15.0 |
| 4 VII | 3.0 | 5.3 | .9 | 53.5 | .0 | 4.6 | 4.9 | 1.0 | 1.9 | .6 | .6 | .5 | .6 |
| 5 VIII-SOUTH | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 VI-EAST | 18.0 | .9 | .2 | 8.2 | 89.6 | 81.7 | .3 | 3.7 | .4 | .1 | .1 | .2 | .2 |
| 7 V-SOUTH | 0.0 | 23.0 | 9.7 | 21.9 | 0.0 | 1.5 | 64.7 | 4.0 | 22.3 | 21.9 | 7.7 | 4.8 | 4.9 |
| 8 IV-SOUTH | 4.2 | 2.2 | .9 | 5.8 | .0 | 10.0 | 1.9 | 84.4 | 15.0 | 1.7 | .6 | 1.1 | .5 |
| 9 IV-NORTH | .1 | 3.3 | 2.2 | 1.9 | 0.0 | 1.4 | 9.6 | 6.2 | 49.8 | 5.5 | 1.0 | 1.6 | .9 |
| 10 III | .7 | .4 | 4.5 | .1 | 0.0 | .1 | 6.6 | .3 | 8.7 | 61.8 | 22.4 | 11.3 | 6.7 |
| 11 II | 0.0 | .0 | 3.5 | 0.0 | 0.0 | 0.0 | .0 | 0.0 | .0 | 1.7 | 35.1 | 14.1 | 5.2 |
| 12 I | 0.0 | 0.0 | .1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .0 | .2 | 16.3 | 47.2 | 8.8 |
| 13 S. QUEBEC | 0.0 | .3 | 8.9 | 0.0 | 0.0 | 0.0 | .1 | 0.0 | .0 | .1 | 1.5 | 9.0 | 53.3 |

## TABLE 4 (concluded)

### (d) APRIL 1978

TOTAL CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS (kilotons)

| | EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | VIII-NORTH | .7 | .0 | .0 | .1 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 2 | V-NORTH | 2.7 | 58.7 | 8.8 | 6.5 | .0 | .6 | 23.4 | .2 | 2.2 | 4.4 | 1.4 | 1.0 | .5 |
| 3 | S. ONTARIO | .3 | 11.3 | 59.5 | 1.1 | .0 | .3 | 7.6 | .3 | 1.2 | 6.1 | 3.7 | 1.3 | 2.2 |
| 4 | VII | 1.8 | 2.7 | .2 | 32.4 | .0 | 1.5 | 9.8 | 1.1 | 1.8 | .4 | .1 | .1 | .0 |
| 5 | VIII-SOUTH | 0.0 | 0.0 | 0.0 | .0 | .0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 | VI-EAST | .4 | .5 | .1 | 5.7 | .1 | 27.3 | 1.5 | 3.9 | 1.4 | .3 | .1 | .0 | .0 |
| 7 | V-SOUTH | 1.5 | 13.0 | 6.5 | 25.4 | .0 | 1.8 | 137.5 | 3.3 | 34.8 | 31.4 | 4.1 | 2.5 | 1.2 |
| 8 | IV-SOUTH | .0 | .1 | .1 | 1.0 | 0.0 | 1.2 | 1.6 | 69.5 | 24.9 | 3.4 | .4 | .2 | .1 |
| 9 | IV-NORTH | .0 | .2 | 1.3 | 3.4 | .0 | .7 | 20.1 | 5.6 | 71.0 | 9.4 | .9 | .7 | .5 |
| 10 | III | 0.0 | .6 | 2.7 | .0 | 0.0 | .1 | 19.8 | .8 | 13.1 | 100.9 | 7.3 | 4.0 | 1.3 |
| 11 | II | .0 | .2 | 4.7 | .0 | .0 | .0 | .5 | .1 | .5 | 5.2 | 12.5 | 4.1 | .6 |
| 12 | I | 0.0 | .0 | .7 | 0.0 | 0.0 | 0.0 | .0 | .0 | .3 | 2.0 | 5.5 | 13.5 | 1.3 |
| 13 | S. QUEBEC | .1 | .4 | 13.3 | .1 | 0.0 | .0 | .2 | .0 | .1 | .4 | 1.2 | 3.1 | 10.6 |
| | TOTAL (KTON S) | 7.6 | 87.8 | 97.9 | 75.6 | .1 | 33.5 | 221.9 | 85.0 | 151.1 | 164.0 | 37.2 | 30.6 | 18.4 |

PERCENT CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS

| | EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | VIII-NORTH | 9.8 | .1 | .0 | .1 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 2 | V-NORTH | 36.3 | 66.9 | 9.0 | 8.5 | 2.2 | 1.7 | 10.6 | .3 | 1.4 | 2.7 | 3.8 | 3.3 | 2.6 |
| 3 | S. ONTARIO | 3.9 | 12.9 | 60.8 | 1.4 | 1.1 | .9 | 3.4 | .3 | .8 | 3.7 | 10.1 | 4.4 | 12.1 |
| 4 | VII | 24.3 | 3.1 | .2 | 42.8 | 1.6 | 4.4 | 4.4 | 1.3 | 1.2 | .2 | .3 | .3 | .2 |
| 5 | VIII-SOUTH | 0.0 | 0.0 | 0.0 | .0 | 1.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 | VI-EAST | 4.8 | .5 | .2 | 7.6 | 91.7 | 81.6 | .7 | 4.6 | .9 | .2 | .2 | .1 | .2 |
| 7 | V-SOUTH | 19.7 | 14.8 | 6.6 | 33.6 | 1.8 | 5.5 | 62.0 | 3.9 | 23.0 | 19.2 | 11.0 | 8.3 | 6.5 |
| 8 | IV-SOUTH | .1 | .1 | .1 | 1.3 | 0.0 | 3.6 | .7 | 81.8 | 16.5 | 2.1 | 1.2 | .7 | .5 |
| 9 | IV-NORTH | .4 | .2 | 1.4 | 4.4 | .0 | 2.1 | 9.0 | 6.6 | 47.0 | 5.7 | 2.4 | 2.3 | 2.5 |
| 10 | III | 0.0 | .7 | 2.7 | .0 | 0.0 | .2 | 8.9 | .9 | 8.7 | 61.6 | 19.6 | 13.1 | 7.3 |
| 11 | II | .0 | .2 | 4.8 | .0 | .0 | .1 | .2 | .2 | .3 | 3.2 | 33.6 | 13.3 | 3.5 |
| 12 | I | 0.0 | .0 | .7 | 0.0 | 0.0 | 0.0 | .0 | .0 | .2 | 1.2 | 14.6 | 44.1 | 7.0 |
| 13 | S. QUEBEC | .8 | .5 | 13.6 | .1 | 0.0 | .0 | .1 | .1 | .1 | .2 | 3.2 | 10.1 | 57.6 |

*All results are based on emission data for 1977. A value of 0.0 in the tables indicates no sulfur deposition occurred; a value of .0 signifies a sulfur deposition of less than 0.05 ktons.

## TABLE 5. CALCULATED INTERREGIONAL EXCHANGES OF SULFUR FOR OCTOBER 1975, 1976, 1977, 1978*

### (a) OCTOBER 1975

TOTAL CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS (kilotons)

| EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 VIII-NORTH | .7 | .0 | .0 | .1 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 2 V-NORTH | 3.1 | 52.2 | 13.9 | 5.1 | .0 | .6 | 23.5 | .9 | 5.3 | 6.2 | 1.7 | .7 | .9 |
| 3 S. ONTARIO | .3 | 7.2 | 65.9 | .2 | 0.0 | .1 | 6.7 | .1 | 1.8 | 10.5 | 4.5 | 1.3 | 2.3 |
| 4 VII | 2.8 | 6.5 | 1.2 | 25.0 | .0 | 2.1 | 8.3 | .9 | 1.5 | .5 | .5 | .1 | .2 |
| 5 VIII-SOUTH | 0.0 | 0.0 | 0.0 | .0 | .0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 VI-EAST | 1.0 | .6 | .3 | 4.1 | .1 | 26.5 | 1.3 | 3.1 | 1.1 | .3 | .1 | .0 | .1 |
| 7 V-SOUTH | 3.0 | 19.6 | 10.8 | 15.6 | .0 | 1.6 | 111.4 | 6.8 | 36.0 | 34.7 | 5.4 | 2.3 | 3.2 |
| 8 IV-SOUTH | .1 | .1 | .9 | .3 | .0 | 2.5 | 1.3 | 67.0 | 18.0 | 3.5 | 1.1 | .8 | .4 |
| 9 IV-NORTH | .5 | 1.0 | 2.5 | 1.5 | .0 | 1.2 | 16.0 | 12.1 | 67.9 | 9.1 | 1.4 | 1.4 | 1.0 |
| 10 III | 0.0 | .0 | 3.5 | 0.0 | 0.0 | 0.0 | 14.2 | .1 | 13.3 | 97.7 | 10.4 | 3.3 | 3.4 |
| 11 II | 0.0 | .0 | 3.7 | 0.0 | 0.0 | 0.0 | .0 | 0.0 | .0 | 3.8 | 13.7 | 3.2 | 1.1 |
| 12 I | 0.0 | 0.0 | .3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .0 | .3 | 6.1 | 14.6 | 1.2 |
| 13 S. QUEBEC | .0 | .1 | 14.5 | .0 | 0.0 | .0 | .1 | .0 | .0 | .6 | 1.1 | 2.8 | 10.9 |
| TOTAL (KTON S) | 11.6 | 87.5 | 117.7 | 52.0 | .1 | 34.6 | 182.6 | 91.0 | 144.9 | 167.0 | 46.0 | 30.4 | 24.7 |

PERCENT CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS

| EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 VIII-NORTH | 5.8 | .1 | .0 | .2 | .2 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 2 V-NORTH | 26.7 | 59.7 | 11.9 | 9.9 | 7.3 | 1.7 | 12.9 | 1.0 | 3.7 | 3.7 | 3.8 | 2.3 | 3.7 |
| 3 S. ONTARIO | 2.8 | 8.3 | 56.0 | .5 | 0.0 | .2 | 3.7 | .2 | 1.2 | 6.3 | 9.7 | 4.4 | 9.4 |
| 4 VII | 24.4 | 7.4 | 1.0 | 48.1 | 4.9 | 6.1 | 4.5 | 1.0 | 1.0 | .3 | 1.1 | .5 | .9 |
| 5 VIII-SOUTH | 0.0 | 0.0 | 0.0 | .0 | 2.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 VI-EAST | 8.5 | .7 | .3 | 8.0 | 63.4 | 76.6 | .7 | 3.5 | .8 | .2 | .3 | .1 | .5 |
| 7 V-SOUTH | 26.2 | 22.4 | 9.2 | 30.0 | 18.9 | 4.7 | 61.0 | 7.5 | 24.9 | 20.7 | 11.7 | 7.4 | 13.1 |
| 8 IV-SOUTH | .9 | .1 | .7 | .5 | 2.2 | 7.2 | .7 | 73.6 | 12.4 | 2.1 | 2.4 | 2.6 | 1.6 |
| 9 IV-NORTH | 4.4 | 1.1 | 2.2 | 2.9 | .7 | 3.4 | 8.8 | 13.3 | 45.8 | 5.5 | 3.1 | 4.5 | 4.1 |
| 10 III | 0.0 | .0 | 3.0 | 0.0 | 0.0 | 0.0 | 7.8 | .1 | 9.2 | 58.5 | 22.7 | 10.8 | 13.6 |
| 11 II | 0.0 | .0 | 3.2 | 0.0 | 0.0 | 0.0 | .0 | 0.0 | .0 | 2.3 | 29.8 | 10.4 | 4.5 |
| 12 I | 0.0 | 0.0 | .2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .0 | .2 | 13.2 | 47.9 | 4.7 |
| 13 S. QUEBEC | .2 | .1 | 12.4 | .0 | 0.0 | .0 | .0 | .0 | .0 | .4 | 2.4 | 9.1 | 44.0 |

## TABLE 5 (continued)

### (b) OCTOBER 1976

TOTAL CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS (kilotons)

| EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 VIII-NORTH | .6 | .1 | .0 | .1 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 2 V-NORTH | .5 | 52.9 | 16.8 | 6.4 | .0 | 1.6 | 23.8 | 1.0 | 3.2 | 4.9 | 2.8 | 1.4 | 1.7 |
| 3 S. ONTARIO | .0 | 6.7 | 66.8 | .0 | 0.0 | .7 | 7.4 | .9 | 2.3 | 5.3 | 5.3 | 2.5 | 5.2 |
| 4 VII | .1 | 2.8 | 1.1 | 30.4 | .0 | 5.7 | 7.8 | 1.7 | 2.4 | .6 | .4 | .2 | .3 |
| 5 VIII-SOUTH | 0.0 | 0.0 | 0.0 | .0 | .0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 VI-EAST | .0 | .0 | .0 | 2.5 | .0 | 30.1 | .4 | 1.8 | .3 | .0 | .0 | .0 | .0 |
| 7 V-SOUTH | .0 | 14.4 | 14.8 | 12.9 | .0 | 8.6 | 122.6 | 10.3 | 40.1 | 28.7 | 5.1 | 2.2 | 2.2 |
| 8 IV-SOUTH | 0.0 | .1 | .0 | .3 | 0.0 | 4.7 | 2.7 | 70.0 | 19.2 | 1.3 | .1 | .0 | .0 |
| 9 IV-NORTH | 0.0 | 2.4 | 1.5 | .9 | 0.0 | 3.3 | 19.9 | 14.9 | 71.4 | 8.8 | .8 | .4 | .3 |
| 10 III | 0.0 | 1.1 | 11.9 | .0 | 0.0 | .5 | 18.2 | 3.9 | 18.2 | 110.1 | 10.7 | 3.7 | 1.6 |
| 11 II | 0.0 | .2 | 5.2 | .0 | 0.0 | .0 | .5 | .2 | .5 | 5.9 | 15.5 | 4.3 | 1.5 |
| 12 I | 0.0 | .0 | .2 | 0.0 | 0.0 | 0.0 | .1 | .1 | .2 | 2.4 | 7.4 | 16.9 | 2.8 |
| 13 S. QUEBEC | 0.0 | .0 | 10.6 | .0 | 0.0 | .1 | .1 | .1 | .1 | .3 | 1.0 | 2.2 | 15.3 |
| TOTAL (KTON S) | 1.2 | 80.6 | 129.1 | 53.6 | .0 | 55.3 | 203.5 | 104.8 | 157.8 | 168.3 | 49.2 | 33.9 | 31.0 |

PERCENT CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS

| EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 VIII-NORTH | 50.8 | .1 | .0 | .2 | 2.9 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 2 V-NORTH | 39.1 | 65.5 | 13.0 | 12.0 | 16.0 | 3.0 | 11.7 | .9 | 2.0 | 2.9 | 5.7 | 4.3 | 5.4 |
| 3 S. ONTARIO | .0 | 8.3 | 51.8 | .0 | 0.0 | 1.3 | 3.6 | .8 | 1.4 | 3.2 | 10.8 | 7.4 | 16.8 |
| 4 VII | 8.5 | 3.4 | .8 | 56.7 | 20.2 | 10.3 | 3.8 | 1.6 | 1.5 | .4 | .7 | .6 | 1.1 |
| 5 VIII-SOUTH | 0.0 | 0.0 | 0.0 | .0 | 4.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 VI-EAST | 1.4 | .0 | .0 | 4.7 | 50.7 | 54.4 | .2 | 1.7 | .2 | .0 | .0 | .0 | .0 |
| 7 V-SOUTH | .2 | 17.8 | 11.5 | 24.0 | 5.6 | 15.5 | 60.2 | 9.8 | 25.4 | 17.0 | 10.3 | 6.4 | 7.0 |
| 8 IV-SOUTH | 0.0 | .2 | .0 | .6 | 0.0 | 8.4 | 1.3 | 66.8 | 12.1 | .8 | .1 | .0 | .0 |
| 9 IV-NORTH | 0.0 | 3.0 | 1.2 | 1.6 | 0.0 | 6.0 | 9.8 | 14.3 | 45.2 | 5.2 | 1.7 | 1.3 | .9 |
| 10 III | 0.0 | 1.3 | 9.2 | .1 | 0.0 | .9 | 9.0 | 3.7 | 11.5 | 65.4 | 21.8 | 10.8 | 5.2 |
| 11 II | 0.0 | .2 | 4.1 | .0 | 0.0 | .0 | .3 | .2 | .3 | 3.5 | 31.6 | 12.7 | 4.8 |
| 12 I | 0.0 | .1 | .2 | 0.0 | 0.0 | 0.0 | .0 | .1 | .1 | 1.4 | 15.1 | 50.1 | 9.2 |
| 13 S. QUEBEC | 0.0 | .0 | 8.2 | .0 | 0.0 | .1 | .1 | .1 | .1 | .2 | 2.1 | 6.4 | 49.5 |

## TABLE 5 (continued)

### (c) OCTOBER 1977

TOTAL CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS (kilotons)

| EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 VIII-NORTH | .8 | .1 | .0 | .1 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 2 V-NORTH | 1.0 | 55.2 | 21.4 | 5.5 | .0 | .6 | 21.1 | 1.0 | 3.8 | 7.2 | 3.1 | 1.0 | 1.1 |
| 3 S. ONTARIO | .1 | 8.2 | 69.4 | .5 | .0 | .2 | 6.5 | .5 | 1.5 | 7.7 | 6.0 | 2.0 | 4.6 |
| 4 VII | .1 | 3.3 | .5 | 31.5 | .0 | 2.3 | 9.4 | 2.2 | 2.7 | 1.1 | .3 | .0 | .1 |
| 5 VIII-SOUTH | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 VI-EAST | .1 | .1 | .0 | 3.4 | .0 | 30.9 | .6 | 2.5 | .8 | .0 | .0 | .0 | .0 |
| 7 V-SOUTH | .5 | 18.5 | 13.0 | 15.4 | .0 | 2.5 | 123.2 | 8.8 | 41.2 | 35.9 | 6.8 | .9 | 1.9 |
| 8 IV-SOUTH | 0.0 | .4 | .2 | 1.4 | 0.0 | 5.5 | 3.7 | 70.7 | 17.6 | .8 | .0 | .0 | .1 |
| 9 IV-NORTH | .0 | 2.7 | 1.9 | 2.2 | .0 | 1.8 | 18.8 | 14.2 | 73.3 | 9.6 | .8 | .1 | .5 |
| 10 III | .1 | 3.3 | 9.7 | 1.0 | .0 | .4 | 22.4 | 4.4 | 20.3 | 105.4 | 12.7 | 1.8 | 2.9 |
| 11 II | .0 | .3 | 5.3 | .1 | .0 | .0 | .5 | .2 | 1.1 | 5.8 | 17.1 | 4.4 | 1.1 |
| 12 I | 0.0 | .0 | .2 | .0 | 0.0 | .0 | .2 | .1 | .8 | 2.5 | 9.5 | 19.0 | 1.9 |
| 13 S. QUEBEC | .0 | .2 | 11.2 | .1 | 0.0 | .0 | .1 | .0 | .1 | .6 | 1.4 | 2.9 | 14.4 |
| TOTAL (KTON S) | 2.9 | 92.2 | 133.0 | 61.3 | .0 | 44.2 | 206.6 | 104.7 | 163.2 | 176.5 | 57.8 | 32.1 | 28.5 |

PERCENT CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS

| EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 VIII-NORTH | 27.7 | .1 | .0 | .2 | 1.5 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 2 V-NORTH | 34.8 | 59.8 | 16.1 | 9.0 | 9.0 | 1.3 | 10.2 | 1.0 | 2.3 | 4.1 | 5.4 | 3.1 | 3.7 |
| 3 S. ONTARIO | 5.2 | 8.9 | 52.2 | .9 | 4.5 | .4 | 3.1 | .5 | .9 | 4.4 | 10.4 | 6.2 | 16.2 |
| 4 VII | 4.0 | 3.6 | .4 | 51.5 | 3.9 | 5.3 | 4.6 | 2.1 | 1.6 | .6 | .6 | .1 | .3 |
| 5 VIII-SOUTH | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 VI-EAST | 3.0 | .1 | .0 | 5.5 | 54.6 | 69.8 | .3 | 2.4 | .5 | .0 | .0 | .0 | .0 |
| 7 V-SOUTH | 18.3 | 20.0 | 9.8 | 25.1 | 22.3 | 5.7 | 59.6 | 8.4 | 25.3 | 20.3 | 11.7 | 2.9 | 6.5 |
| 8 IV-SOUTH | 0.0 | .4 | .2 | 2.3 | 0.0 | 12.4 | 1.8 | 67.5 | 10.8 | .5 | .0 | .0 | .2 |
| 9 IV-NORTH | .9 | 2.9 | 1.4 | 3.6 | 3.7 | 4.1 | 9.1 | 13.6 | 44.9 | 5.4 | 1.4 | .5 | 1.7 |
| 10 III | 4.5 | 3.5 | 7.3 | 1.7 | .5 | .8 | 10.9 | 4.2 | 12.5 | 59.7 | 21.9 | 5.6 | 10.2 |
| 11 II | 1.4 | .4 | 4.0 | .1 | .0 | .1 | .2 | .2 | .7 | 3.3 | 29.6 | 13.7 | 3.8 |
| 12 I | 0.0 | .0 | .2 | .0 | 0.0 | .0 | .1 | .1 | .5 | 1.4 | 16.5 | 59.1 | 6.8 |
| 13 S. QUEBEC | .2 | .2 | 8.4 | .1 | 0.0 | .1 | .1 | .0 | .0 | .3 | 2.4 | 8.9 | 50.4 |

## TABLE 5 (concluded)

### (d) OCTOBER 1978

TOTAL CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS (kilotons)

| EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 VIII-NORTH | .6 | .1 | .0 | .1 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 2 V-NORTH | .0 | 52.0 | 32.1 | 2.4 | 0.0 | .1 | 19.1 | .4 | 1.5 | 5.3 | 2.7 | 1.4 | 2.9 |
| 3 S ONTARIO | .0 | 3.5 | 80.5 | .0 | 0.0 | 0.0 | 3.1 | .0 | .2 | 3.9 | 5.3 | 2.3 | 8.4 |
| 4 VII | .0 | 3.4 | 2.5 | 25.0 | .0 | 2.7 | 12.5 | 1.8 | 3.4 | .5 | .3 | .1 | .4 |
| 5 VIII-SOUTH | 0.0 | 0.0 | 0.0 | .0 | .0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 VI-EAST | .0 | .1 | .1 | 2.4 | .0 | 29.1 | .5 | 1.5 | .8 | .1 | .0 | .0 | .0 |
| 7 V-SOUTH | 0.0 | 14.1 | 22.0 | 6.7 | 0.0 | 1.5 | 131.2 | 5.5 | 35.9 | 34.5 | 6.7 | 2.0 | 4.8 |
| 8 IV-SOUTH | 0.0 | .1 | .2 | .1 | .0 | 5.6 | 1.5 | 63.8 | 17.4 | 3.2 | .3 | .2 | .2 |
| 9 IV-NORTH | 0.0 | .5 | 2.4 | .7 | 0.0 | 2.1 | 21.0 | 11.8 | 71.6 | 11.4 | 1.9 | .6 | 1.1 |
| 10 III | 0.0 | .0 | 8.1 | .0 | 0.0 | .0 | 15.9 | 2.1 | 13.3 | 110.7 | 15.2 | 4.1 | 6.0 |
| 11 II | 0.0 | .0 | 5.4 | 0.0 | 0.0 | 0.0 | .1 | .1 | .3 | 2.9 | 16.4 | 5.0 | 2.6 |
| 12 I | 0.0 | 0.0 | .1 | 0.0 | 0.0 | 0.0 | .0 | .1 | .1 | .4 | 6.4 | 17.4 | 4.5 |
| 13 S. QUEBEC | 0.0 | 0.0 | 8.0 | 0.0 | 0.0 | 0.0 | 0.0 | .0 | .0 | .0 | .4 | 2.4 | 19.0 |
| TOTAL (KTON S) | .6 | 73.8 | 161.5 | 37.4 | .0 | 41.0 | 204.7 | 87.2 | 144.7 | 173.0 | 55.8 | 35.6 | 49.8 |

PERCENT CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS

| EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 VIII-NORTH | 96.7 | .1 | .0 | .4 | 6.3 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 2 V-NORTH | 2.0 | 70.5 | 19.9 | 6.3 | 0.0 | .2 | 9.3 | .4 | 1.0 | 3.1 | 4.9 | 3.9 | 5.8 |
| 3 S. ONTARIO | .0 | 4.8 | 49.8 | .0 | 0.0 | 0.0 | 1.5 | .0 | .2 | 2.3 | 9.6 | 6.5 | 16.8 |
| 4 VII | .6 | 4.7 | 1.5 | 66.8 | 1.0 | 6.6 | 6.1 | 2.0 | 2.3 | .3 | .5 | .3 | .9 |
| 5 VIII-SOUTH | 0.0 | 0.0 | 0.0 | .0 | 16.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 VI-EAST | .6 | .2 | .1 | 6.4 | 75.8 | 70.9 | .2 | 1.8 | .6 | .1 | .1 | .0 | .0 |
| 7 V-SOUTH | 0.0 | 19.1 | 13.6 | 17.8 | 0.0 | 3.6 | 64.1 | 6.3 | 24.8 | 20.0 | 12.0 | 5.7 | 9.7 |
| 8 IV-SOUTH | 0.0 | .1 | .1 | .2 | .9 | 13.6 | .7 | 73.1 | 12.0 | 1.8 | .6 | .5 | .3 |
| 9 IV-NORTH | 0.0 | .6 | 1.5 | 2.0 | 0.0 | 5.1 | 10.3 | 13.6 | 49.5 | 6.6 | 3.4 | 1.8 | 2.2 |
| 10 III | 0.0 | .0 | 5.0 | .0 | 0.0 | .1 | 7.8 | 2.4 | 9.2 | 64.0 | 27.2 | 11.6 | 12.0 |
| 11 II | 0.0 | .0 | 3.4 | 0.0 | 0.0 | 0.0 | .0 | .2 | .2 | 1.7 | 29.4 | 14.0 | 5.3 |
| 12 I | 0.0 | 0.0 | .1 | 0.0 | 0.0 | 0.0 | .0 | .1 | .1 | .2 | 11.5 | 49.0 | 9.0 |
| 13 S. QUEBEC | 0.0 | 0.0 | 4.9 | 0.0 | 0.0 | 0.0 | 0.0 | .0 | .0 | .0 | .7 | 6.7 | 38.0 |

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*All results are based on emission data for 1977. A value of 0.0 in the tables indicates no sulfur deposition occurred; a value of .0 signifies a sulfur deposition of less than 0.05 ktons.

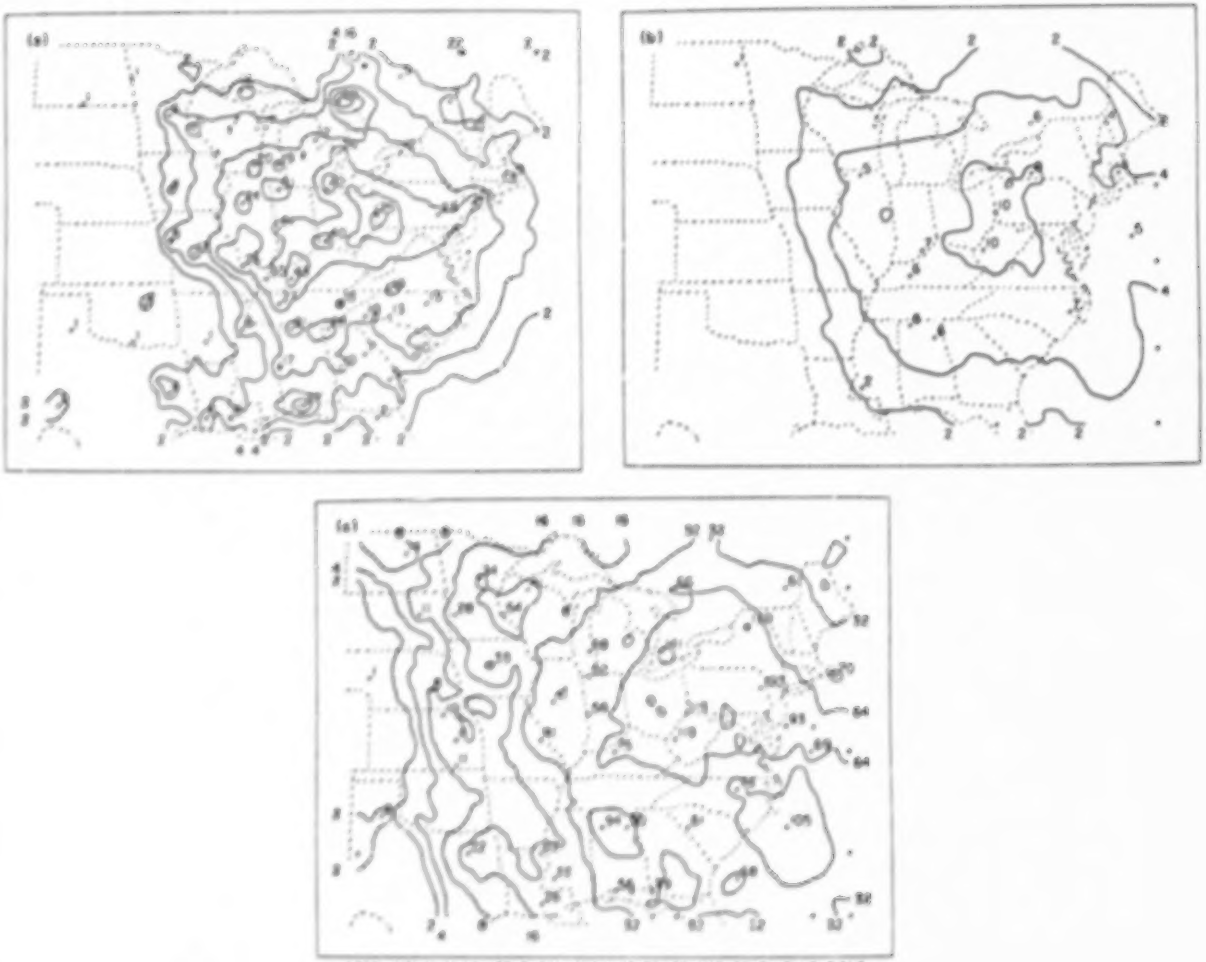
## SECTION 7

## CALCULATED ANNUAL VALUES (1975, 1976, 1978) AND AUGUST 1977

The calculated annual $SO_2$ and $SO_4^{=}$ concentrations ($\mu g/m^3$) and $SO_4^{=}$ wet depositions ($mg/m^2 \times 10$) for the four years 1975, 1976, 1977, and 1978 are shown in Figures 50 through 53. The calculated annual interregional exchanges of sulfur between the different EPA regions are given in Table 6. The annual graphical results for the $SO_2$ and $SO_4^{=}$ dry depositions and $SO_2$ wet depositions are shown in Appendix B. The patterns for any one of the parameters are very similar over the four years. Some differences are apparent in the $SO_4^{=}$ concentrations and wet depositions. The average $SO_4^{=}$ concentrations for 1976 are not as high over the western half of the domain, compared with the other years, and the maximum $SO_4^{=}$ concentrations for 1977 are greater than those for the other years, with values up to 13 $\mu g/m^3$. The $SO_4^{=}$ wet depositions for each of the four years have patterns similar to the $SO_4^{=}$ concentrations. The largest deposition values are over the Northeast, with higher values (>128 $\mu g/m^3$) during the latter two of the four years. The most noticeable difference is that the $SO_4^{=}$ wet depositions for 1977 show a displacement of the center of maximum values to the northeast. This displacement was caused by the unusually high $SO_4^{=}$ wet-deposition values over the northeastern United States in October 1977 (see Figure 48).

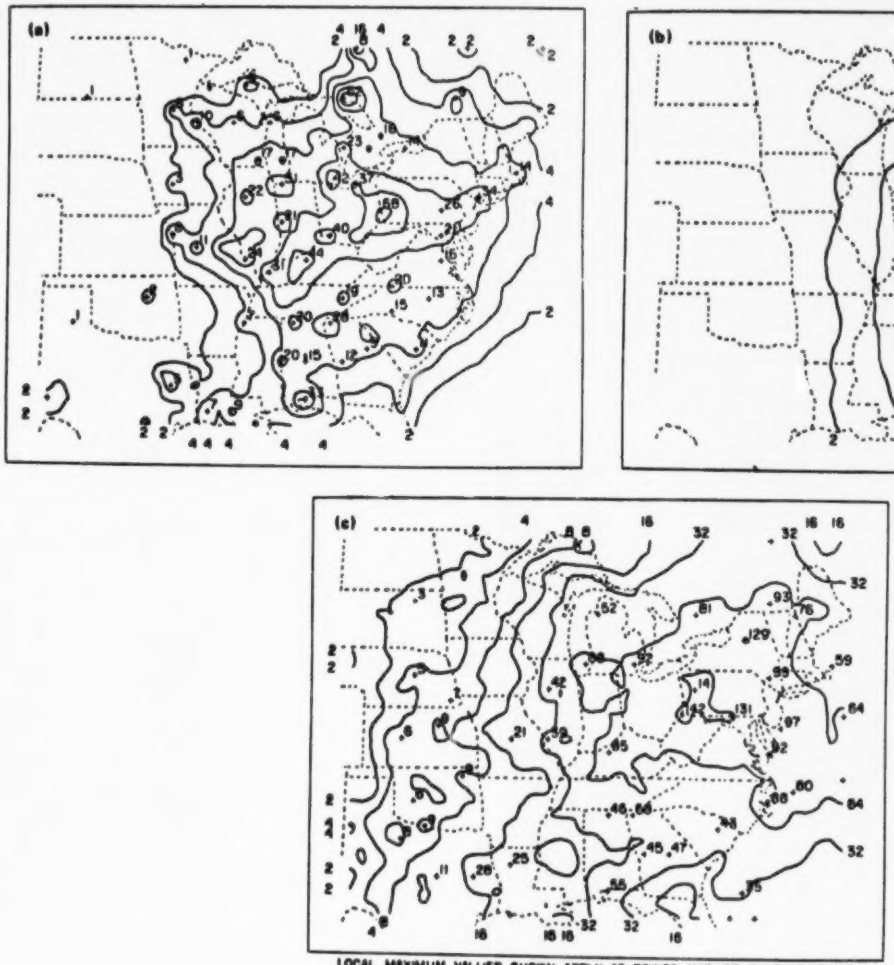
The annual sulfur interregional exchange values in Table 6 are also quite similar from year to year except in the low-emission region VIII North. In 1975, this region (VIII-North) had more sulfur deposited on its soil than in any of the four years (75 ktons, 12 percent from its own emissions and 74 percent from emissions of Regions V-North, VII, and V-South). In 1977, it had the least amount deposited on its soil (18 ktons, 35 percent from its own emissions and 31 percent from the other three regions).

These annual results support the validity of using only the four months January, April, July, and October to calculate reasonable estimates of annual values for pollutant concentrations and depositions.



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

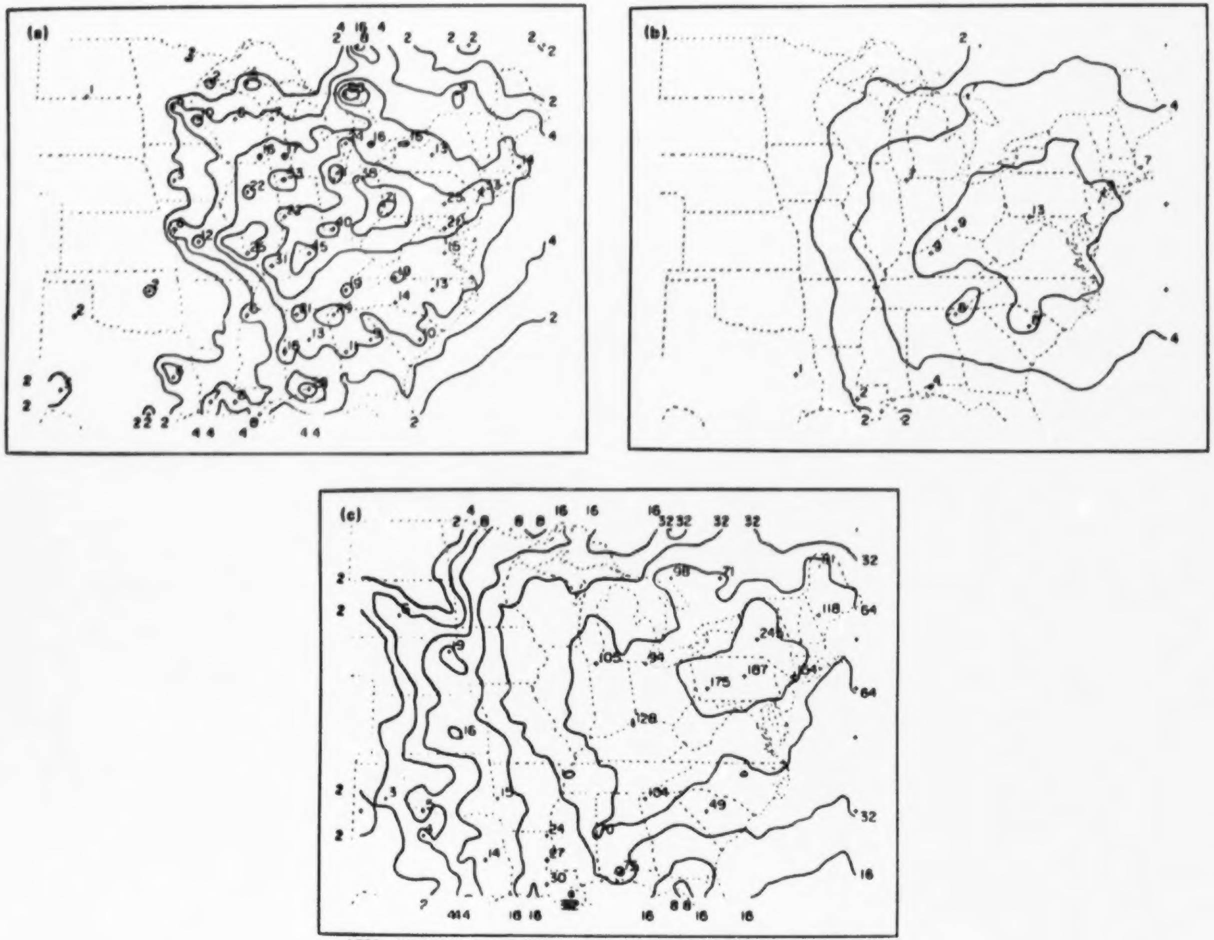
Figure 50. Annual results for 1975.
(a) $SO_2$ concentrations ($\mu g/m^3$), (b) $SO_4^=$ concentrations ($\mu g/m^3$), (c) $SO_4^=$ wet depositions ($mg/m^2 \times 10$).



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

Figure 51. Annual results for 1976.

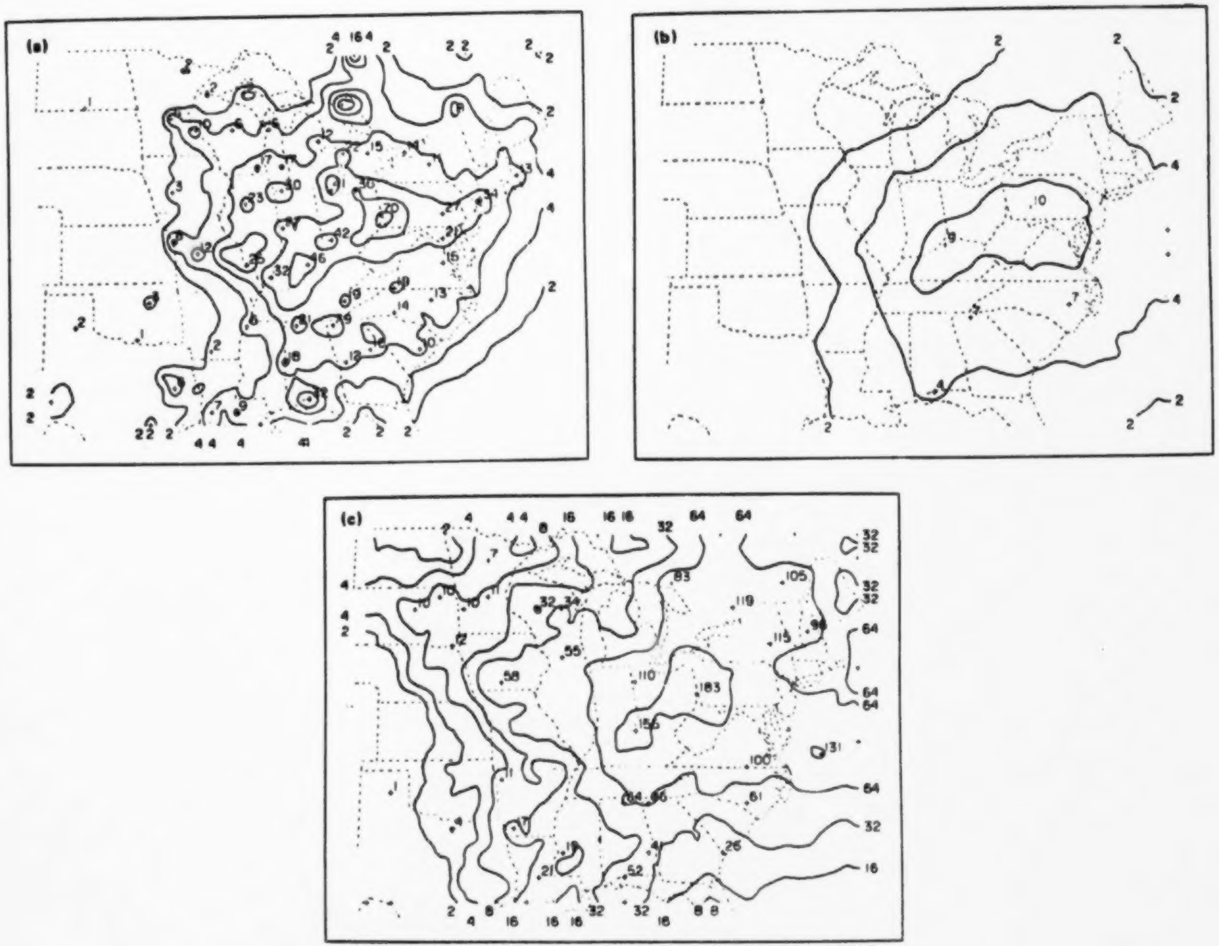
(a) $SO_2$ concentrations ($\mu g/m^3$), (b) $SO_4^=$ concentrations ($\mu g/m^3$), (c) $SO_4^=$ wet depositions ($mg/m^2 \times 10$).



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

Figure 52. Annual results for 1977.

(a) $SO_2$ concentrations ($\mu g/m^3$), (b) $SO_4^=$ concentrations ($\mu g/m^3$), (c) $SO_4^=$ wet depositions ($mg/m^2 \times 10$).



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

Figure 53. Annual results for 1978.

(a) $SO_2$ concentrations ($\mu g/m^3$), (b) $SO_4^=$ concentrations ($\mu g/m^3$), (c) $SO_4^=$ wet depositions ($mg/m^2 \times 10$).

## TABLE 6. CALCULATED ANNUAL INTERREGIONAL EXCHANGES OF SULFUR FOR 1975, 1976, 1977, 1978[*]

### (a) ANNUAL 1975

TOTAL CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS (kilotons)

| | EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | VIII-NORTH | 9. | 1. | 0. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 2 | V-NORTH | 18. | 663. | 254. | 42. | 0. | 4. | 231. | 6. | 36. | 81. | 30. | 8. | 15. |
| 3 | S. ONTARIO | 1. | 60. | 842. | 1. | 0. | 1. | 56. | 1. | 13. | 90. | 70. | 22. | 45. |
| 4 | VII | 19. | 75. | 17. | 353. | 0. | 25. | 115. | 16. | 25. | 5. | 5. | 1. | 2. |
| 5 | VIII-SOUTH | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 6 | VI-EAST | 6. | 8. | 4. | 44. | 1. | 384. | 11. | 40. | 9. | 2. | 1. | 0. | 1. |
| 7 | V-SOUTH | 19. | 229. | 156. | 186. | 0. | 16. | 1539. | 71. | 433. | 450. | 57. | 16. | 25. |
| 8 | IV-SOUTH | 1. | 2. | 6. | 8. | 0. | 47. | 20. | 987. | 254. | 33. | 7. | 4. | 2. |
| 9 | IV-NORTH | 2. | 18. | 31. | 35. | 0. | 21. | 255. | 129. | 906. | 110. | 13. | 7. | 7. |
| 10 | III | 0. | 1. | 84. | 0. | 0. | 1. | 171. | 12. | 162 | 1273. | 138. | 34. | 31. |
| 11 | II | 0. | 0 | 35. | 0. | 0. | 0. | 0. | 0. | 0. | 31. | 133. | 28. | 10. |
| 12 | I | 0. | 0. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 4. | 70. | 133. | 13. |
| 13 | S. QUEBEC | 0. | 1. | 113. | 0. | 0. | 0. | 0. | 0. | 0. | 3. | 9. | 32. | 121. |
| | TOTAL (KTON S) | 75. | 1057 | 1543. | 672. | 1. | 498. | 2398. | 1262. | 1838. | 2081. | 532. | 285. | 273. |

PERCENT CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS

| | EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | VIII-NORTH | 12. | 0. | 0. | 0. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 2 | V-NORTH | 24. | 63. | 16. | 6. | 3. | 1. | 10. | 0. | 2. | 4. | 6. | 3. | 6. |
| 3 | S. ONTARIO | 1. | 6. | 55. | 0. | 0. | 0. | 2. | 0. | 1. | 4. | 13. | 8. | 17. |
| 4 | VII | 25. | 7. | 1. | 53. | 2. | 5. | 5. | 1. | 1. | 0. | 1. | 0. | 1. |
| 5 | VIII-SOUTH | 0. | 0. | 0. | 0. | 3. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 6 | VI-EAST | 8. | 1. | 0. | 7. | 76. | 77. | 0. | 3. | 0. | 0. | 0. | 0. | 0. |
| 7 | V-SOUTH | 25. | 22. | 10. | 28. | 8. | 3. | 64. | 6. | 24. | 22. | 11. | 6. | 9. |
| 8 | IV-SOUTH | 1. | 0. | 0. | 1. | 6. | 9. | 1. | 78. | 14. | 2. | 1. | 1. | 1. |
| 9 | IV-NORTH | 3. | 2. | 2. | 5. | 2. | 4. | 11. | 10. | 49. | 5. | 2. | 3. | 3. |
| 10 | III | 0. | 0. | 5. | 0. | 0. | 0. | 7. | 1. | 9. | 61. | 26. | 12. | 11. |
| 11 | II | 0. | 0. | 2. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 25. | 10. | 4. |
| 12 | I | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 13. | 47. | 5. |
| 13 | S. QUEBEC | 0. | 0. | 7. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 2. | 11. | 44. |

## TABLE 6 (continued)

### (b) ANNUAL 1976

TOTAL CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS (kilotons)

| EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 VIII-NORTH | 8. | 1. | 0. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 2 V-NORTH | 10. | 631. | 247. | 60. | 0. | 7. | 252. | 9. | 31. | 83. | 36. | 14. | 22. |
| 3 S. ONTARIO | 0. | 67. | 809. | 0. | 0. | 2. | 58. | 4. | 14. | 83. | 77. | 27. | 76. |
| 4 VII | 5. | 45. | 17. | 342. | 0. | 33. | 132. | 19. | 43. | 13. | 4. | 2. | 4. |
| 5 VIII-SOUTH | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 6 VI-EAST | 1. | 3. | 2. | 33. | 1. | 367. | 9. | 45. | 10. | 2. | 1. | 0. | 0. |
| 7 V-SOUTH | 3. | 157. | 176. | 149. | 0. | 51. | 1443. | 83. | 466. | 502. | 78. | 27. | 35. |
| 8 IV-SOUTH | 0. | 4. | 6. | 2. | 0. | 33. | 25. | 907. | 237. | 29. | 4. | 1. | 1. |
| 9 IV-NORTH | 0. | 15. | 27. | 6. | 0. | 27. | 191. | 145. | 872. | 155. | 20. | 7. | 7. |
| 10 III | 0. | 3. | 65. | 0. | 0. | 2. | 166. | 19. | 159. | 1317. | 154. | 49. | 26. |
| 11 II | 0. | 1. | 51. | 0. | 0. | 0. | 2. | 1. | 2. | 42. | 202. | 56. | 17. |
| 12 I | 0. | 0. | 1. | 0. | 0. | 0. | 0. | 0. | 1. | 9. | 90. | 199. | 27. |
| 13 S. QUEBEC | 0. | 0. | 132. | 0. | 0. | 0. | 1. | 0. | 1. | 3. | 12. | 33. | 186. |
| TOTAL (KTON S) | 26. | 927. | 1534. | 592. | 2. | 523. | 2279. | 1231. | 1836. | 2239. | 677. | 414. | 402. |

PERCENT CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS

| EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 VIII-NORTH | 30. | 0. | 0. | 0. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 2 V-NORTH | 39. | 68. | 16. | 10. | 3. | 1. | 11. | 1. | 2. | 4. | 5. | 3. | 6. |
| 3 S. ONTARIO | 0. | 7. | 53. | 0. | 0. | 0. | 3. | 0. | 1. | 4. | 11. | 6. | 19. |
| 4 VII | 18. | 5. | 1. | 58. | 8. | 6. | 6. | 2. | 2. | 1. | 1. | 0. | 1. |
| 5 VIII-SOUTH | 0. | 0. | 0. | 0. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 6 VI-EAST | 2. | 0. | 0. | 6. | 80. | 70. | 0. | 4. | 1. | 0. | 0. | 0. | 0. |
| 7 V-SOUTH | 10. | 17. | 11. | 25. | 4. | 10. | 63. | 7. | 25. | 22. | 11. | 6. | 9. |
| 8 IV-SOUTH | 0. | 0. | 0. | 0. | 0. | 6. | 1. | 74. | 13. | 1. | 1. | 0. | 0. |
| 9 IV-NORTH | 1. | 2. | 2. | 1. | 2. | 5. | 8. | 12. | 48. | 7. | 3. | 2. | 2. |
| 10 III | 0. | 0. | 4. | 0. | 0. | 0. | 7. | 2. | 9. | 59. | 23. | 12. | 7. |
| 11 II | 0. | 0. | 3. | 0. | 0. | 0. | 0. | 0. | 0. | 2. | 30. | 13. | 4. |
| 12 I | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 13. | 48. | 7. |
| 13 S. QUEBEC | 0. | 0. | 9. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 2. | 8. | 46. |

## TABLE 6 (continued)

### (c) ANNUAL 1977

TOTAL CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS (kilotons)

| | EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | VIII-NORTH | 10. | 1. | 0. | 2. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 2 | V-NORTH | 3. | 655. | 290. | 46. | 0. | 3. | 229. | 6. | 24. | 78. | 50. | 18. | 23. |
| 3 | S. ONTARIO | 0. | 66. | 820. | 2. | 0. | 1. | 49. | 2. | 7. | 74. | 87. | 40. | 87. |
| 4 | VII | 1. | 43. | 10. | 367. | 0. | 26. | 137. | 22. | 41. | 12. | 3. | 2. | 2. |
| 5 | VIII-SOUTH | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 6 | VI-EAST | 1. | 4. | 1. | 40. | 1. | 401. | 7. | 35. | 6. | 1. | 0. | 0. | 0. |
| 7 | V-SOUTH | 2. | 186. | 145. | 135. | 0. | 14. | 1566. | 59. | 425. | 520. | 92. | 30. | 26. |
| 8 | IV-SOUTH | 0. | 8. | 7. | 16. | 0. | 44. | 31. | 949. | 279. | 25. | 2. | 1. | 2. |
| 9 | IV-NORTH | 0. | 19. | 24. | 11. | 0. | 13. | 221. | 108. | 929. | 159. | 15. | 7. | 6. |
| 10 | III | 0. | 11. | 57. | 3. | 0. | 1. | 178. | 14. | 141. | 1363. | 179. | 56. | 21. |
| 11 | II | 0. | 1. | 53. | 0. | 0. | 0. | 1. | 1. | 4. | 37. | 204. | 65. | 14. |
| 12 | I | 0. | 0. | 1. | 0. | 0. | 0. | 1. | 0. | 2. | 9. | 91. | 207. | 22. |
| 13 | S. QUEBEC | 0. | 2. | 105. | 0. | 0. | 0. | 1. | 0. | 0. | 2. | 8. | 41. | 204. |
| | TOTAL (KTON S) | 18. | 997. | 1514. | 621. | 1. | 503. | 2422. | 1197. | 1856. | 2280. | 732. | 467. | 407. |

PERCENT CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS

| | EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | VIII-NORTH | 55. | 0. | 0. | 0. | 6. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 2 | V-NORTH | 19. | 66. | 19. | 7. | 0. | 1. | 9. | 0. | 1. | 3. | 7. | 4. | 6. |
| 3 | S. ONTARIO | 3. | 7. | 54. | 0. | 0. | 0. | 2. | 0. | 0. | 3. | 12. | 9. | 21. |
| 4 | VII | 3. | 4. | 1. | 59. | 0. | 5. | 6. | 2. | 2. | 1. | 0. | 0. | 0. |
| 5 | VIII-SOUTH | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 6 | VI-EAST | 7. | 0. | 0. | 6. | 92. | 80. | 0. | 3. | 0. | 0. | 0. | 0. | 0. |
| 7 | V-SOUTH | 9. | 19. | 10. | 22. | 1. | 3. | 65. | 5. | 23. | 23. | 13. | 6. | 6. |
| 8 | IV-SOUTH | 1. | 1. | 0. | 3. | 0. | 9. | 1. | 79. | 15. | 1. | 0. | 0. | 1. |
| 9 | IV-NORTH | 0. | 2. | 2. | 2. | 0. | 3. | 9. | 9. | 50. | 7. | 2. | 1. | 1. |
| 10 | III | 2. | 1. | 4. | 1. | 0. | 0. | 7. | 1. | 8. | 60. | 24. | 12. | 5. |
| 11 | II | 1. | 0. | 4. | 0. | 0. | 0. | 0. | 0. | 0. | 2. | 28. | 14. | 3. |
| 12 | I | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 12. | 44. | 5. |
| 13 | S. QUEBEC | 0. | 0. | 7. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 9. | 50. |

## TABLE 6 (concluded)

### (d) ANNUAL 1978

TOTAL CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS (kilotons)

| EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 VIII-NORTH | 8. | 1. | 0. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 2 V-NORTH | 9. | 677. | 260. | 58. | 0. | 6. | 266. | 6. | 27. | 64. | 29. | 13. | 20. |
| 3 S. ONTARIO | 1. | 94. | 870. | 4. | 0. | 2. | 70. | 4. | 11. | 57. | 65. | 27. | 64. |
| 4 VII | 6. | 35. | 15. | 361. | 0. | 36. | 136. | 23. | 39. | 7. | 3. | 1. | 3. |
| 5 VIII-SOUTH | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 6 VI-EAST | 1. | 2. | 1. | 39. | 1. | 370. | 8. | 40. | 11. | 2. | 0. | 0. | 0. |
| 7 V-SOUTH | 4. | 139. | 164. | 162. | 0. | 25. | 1659. | 55. | 455. | 445. | 72. | 24. | 35. |
| 8 IV-SOUTH | 0. | 1. | 2. | 6. | 0. | 34. | 16. | 941. | 276. | 31. | 3. | 2. | 1. |
| 9 IV-NORTH | 0. | 3. | 22. | 15. | 0. | 15. | 238. | 106. | 963. | 137. | 14. | 5. | 7. |
| 10 III | 0. | 2. | 55. | 0. | 0. | 0. | 217. | 11. | 143. | 1356. | 151. | 51. | 38. |
| 11 II | 0. | 1. | 66. | 0. | 0. | 0. | 3. | 1. | 3. | 49. | 192. | 58. | 17. |
| 12 I | 0. | 0. | 5. | 0. | 0. | 0. | 0. | 0. | 1. | 14. | 93. | 200. | 29. |
| 13 S. QUEBEC | 0. | 4. | 131. | 0. | 0. | 0. | 2. | 0. | 1. | 2. | 11. | 33. | 192. |
| TOTAL (KTON S) | 29. | 959. | 1592. | 647. | 1. | 489. | 2615. | 1187. | 1931. | 2165. | 633. | 413. | 405. |

PERCENT CONTRIBUTIONS TO S DEPOSITIONS WITHIN RECEPTOR REGIONS

| EMITTER REGION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 VIII-NORTH | 28. | 0. | 0. | 0. | 3. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 2 V-NORTH | 29. | 71. | 16. | 9. | 1. | 1. | 10. | 1. | 1. | 3. | 5. | 3. | 5. |
| 3 S. ONTARIO | 3. | 10. | 55. | 1. | 0. | 0. | 3. | 0. | 1. | 3. | 10. | 7. | 16. |
| 4 VII | 19. | 4. | 1. | 56. | 1. | 7. | 5. | 2. | 2. | 0. | 0. | 0. | 1. |
| 5 VIII-SOUTH | 0. | 0. | 0. | 0. | 3. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 6 VI-EAST | 5. | 0. | 0. | 6. | 91. | 76. | 0. | 3. | 1. | 0. | 0. | 0. | 0. |
| 7 V-SOUTH | 15. | 14. | 10. | 25. | 1. | 5. | 63. | 5. | 24. | 21. | 11. | 6. | 9. |
| 8 IV-SOUTH | 0. | 0. | 0. | 1. | 0. | 7. | 1. | 79. | 14. | 1. | 0. | 0. | 0. |
| 9 IV-NORTH | 0. | 0. | 1. | 2. | 0. | 3. | 9. | 9. | 50. | 6. | 2. | 1. | 2. |
| 10 III | 0. | 0. | 3. | 0. | 0. | 0. | 8. | 1. | 7. | 63. | 24. | 12. | 9. |
| 11 II | 0. | 0. | 4. | 0. | 0. | 0. | 0. | 0. | 0. | 2. | 30. | 14. | 4. |
| 12 I | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 15. | 48. | 7. |
| 13 S. QUEBEC | 1. | 0. | 8. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 2. | 8. | 47. |

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*All results are based on emission data for 1977. A value of 0.0 in the tables indicates no sulfur deposition occurred; a value of .0 signifies a sulfur deposition of less than 0.05 ktons.

## SECTION 8

## SUMMARY AND CONCLUDING REMARKS

In this study, the SRI-developed ENAMAP-1 model was applied for the purpose of determining the significance of yearly variation in weather on the ENAMAP-1 model calculations. To achieve this, the sulfur emission data for 1977 were used with meteorological data for four different years: 1975, 1976, 1977, and 1978. Model calculations were made for the monthly and annual sulfur concentrations, depositions, and regional exchanges. The calculated results were generally consistent with the air quality measurements, although discrepancies may have been caused by the use of 1977 emissions for all four years and by use of certain measurements that were unrepresentative of average values within receptor cells. The yearly variations in the meteorological data were found:

- To produce changes in the $SO_2$ and $SO_4^=$ concentrations and depositions that were consistent with the changes in transport winds and precipitation amounts.
- To be most noticeable in the monthly $SO_4^=$ concentrations and $SO_4^=$ wet depositions; the latter being sensitive to yearly variations in both the boundary layer wind and precipitation amounts.
- To have little effect on the monthly $SO_2$ concentrations, which principally depict the high emission areas.
- To have little effect on the annual fields, since the results for a given year were derived by averaging the results for January, April, July and October of that year.

As noted in this study and its predecessor (Bhumralkar et al., 1980), there are some differences between the calculated and measured results, particularly in regard to seasonal and latitudinal variation. These differences appear to be partially caused by the imperfect simulation of mixing height and the vertical growth of puffs. Also, the neglect of terrain influences is noticeable in the Appalachian region. An improved version of the model (called ENAMAP-2) is being developed with a view to mitigate these limitations.

# REFERENCES

Bhumralkar, C.M., R.L. Mancuso, D.E. Wolf, R.A. Thuillier, K.C. Nitz, and W.B. Johnson, 1980: "Adaptation and Application of a Long-Term Air Pollution Model ENAMAP-1 to Eastern North America," Final Report, Contract 68-02-2959, SRI International, Menlo Park, California.

Johnson, W.B., D.E. Wolf, and R.L. Mancuso, 1978: "Long-Term Regional Patterns and Transfrontier Exchanges of Airborne Sulfur Pollution in Europe," *Atmos. Environ.*, Vol. 12, pp. 511-527.

Mancuso, R.L., C.M. Bhumralkar, D.E. Wolf, and W.B. Johnson, 1978: "Evaluation and Sensitivity Analyses of the European Regional Model of Air Pollution (EURMAP-1)," Progress Report, Contract LUP-411 515/IIIA315, SRI International, Menlo Park, California.

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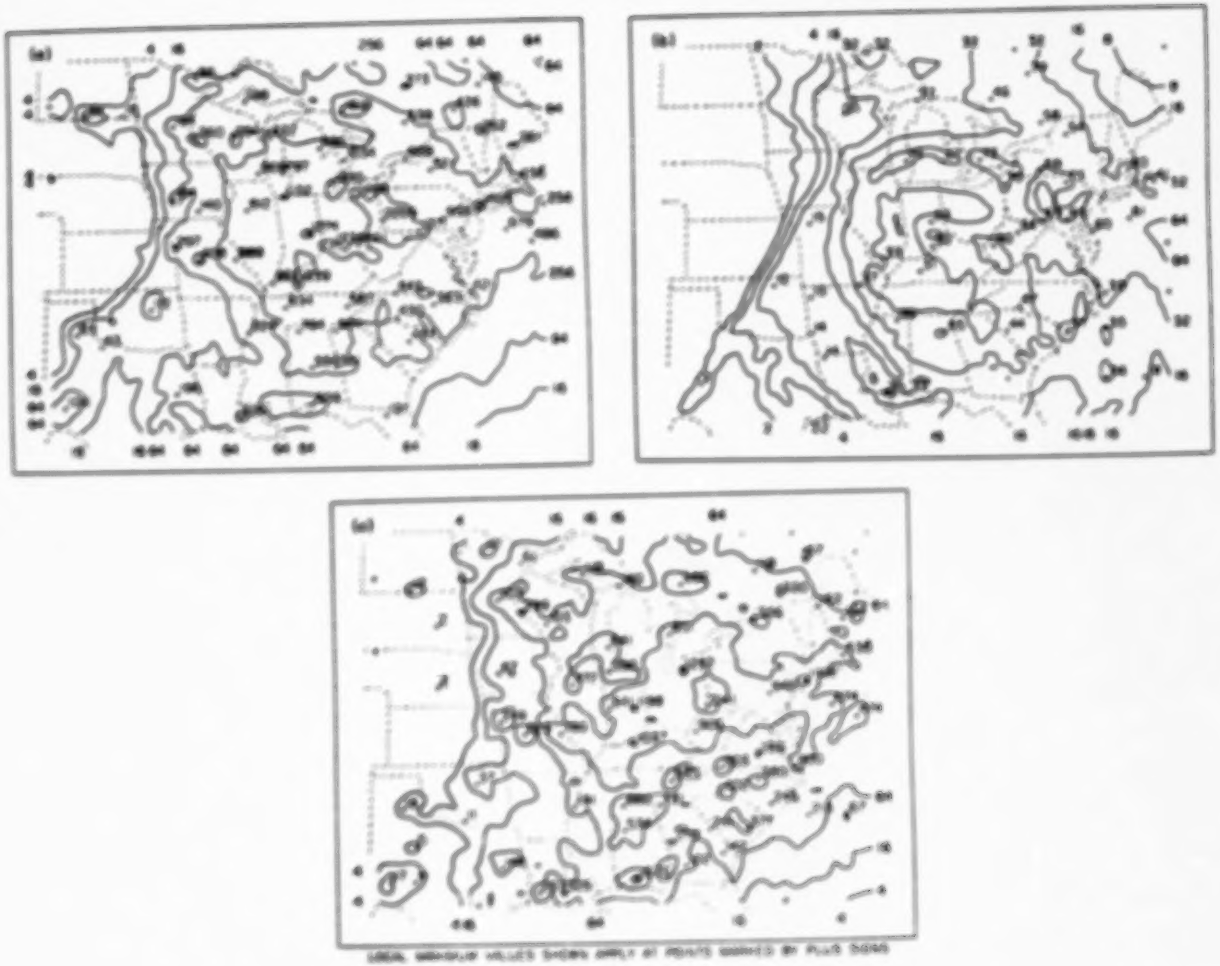
## Appendix A

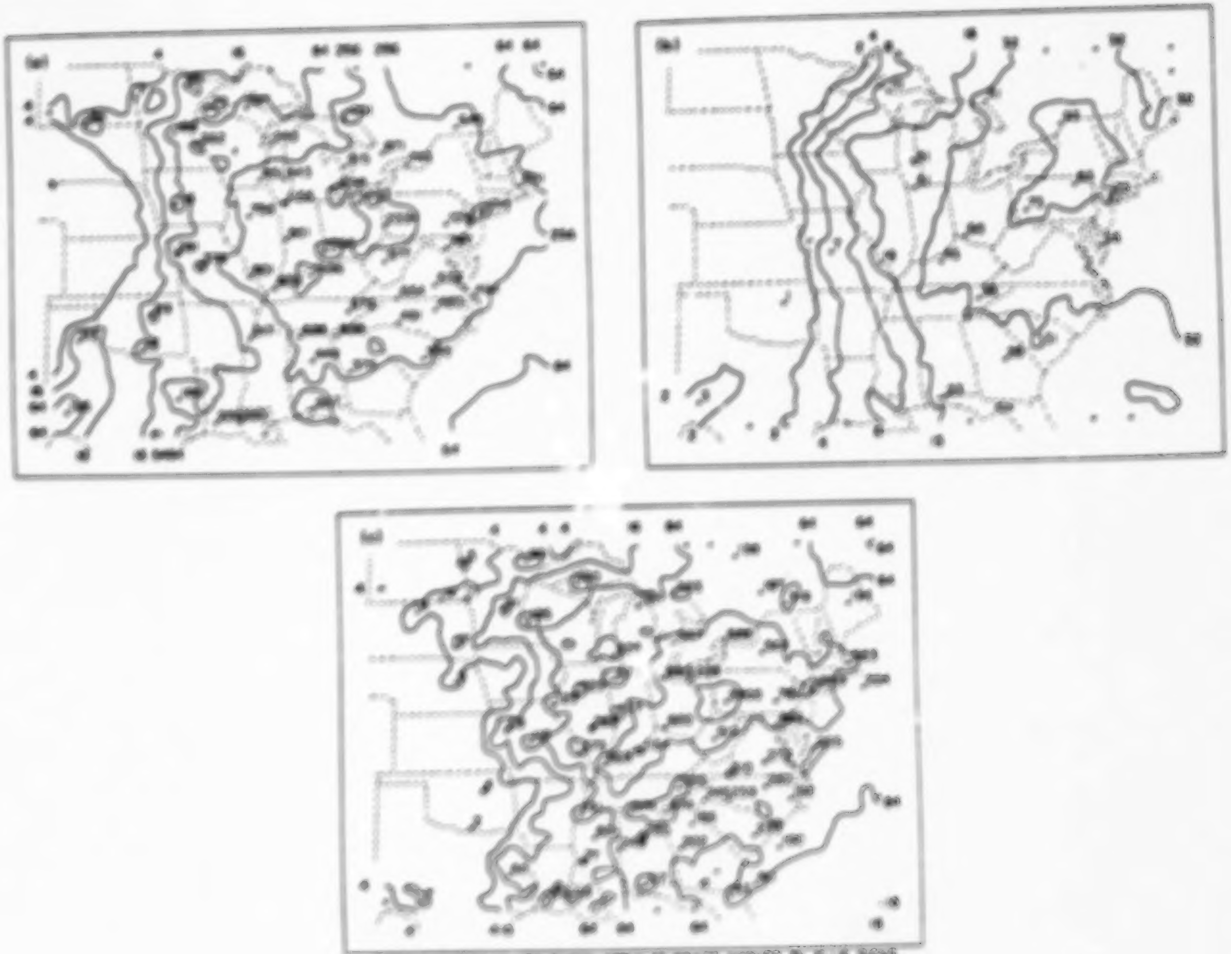
# CALCULATED MONTHLY RESULTS FOR $SO_2$ AND $SO_4^=$ DRY AND $SO_2$ WET DEPOSITIONS ($mg/m^2$)



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

JANUARY 1975 (mg/m$^2$)

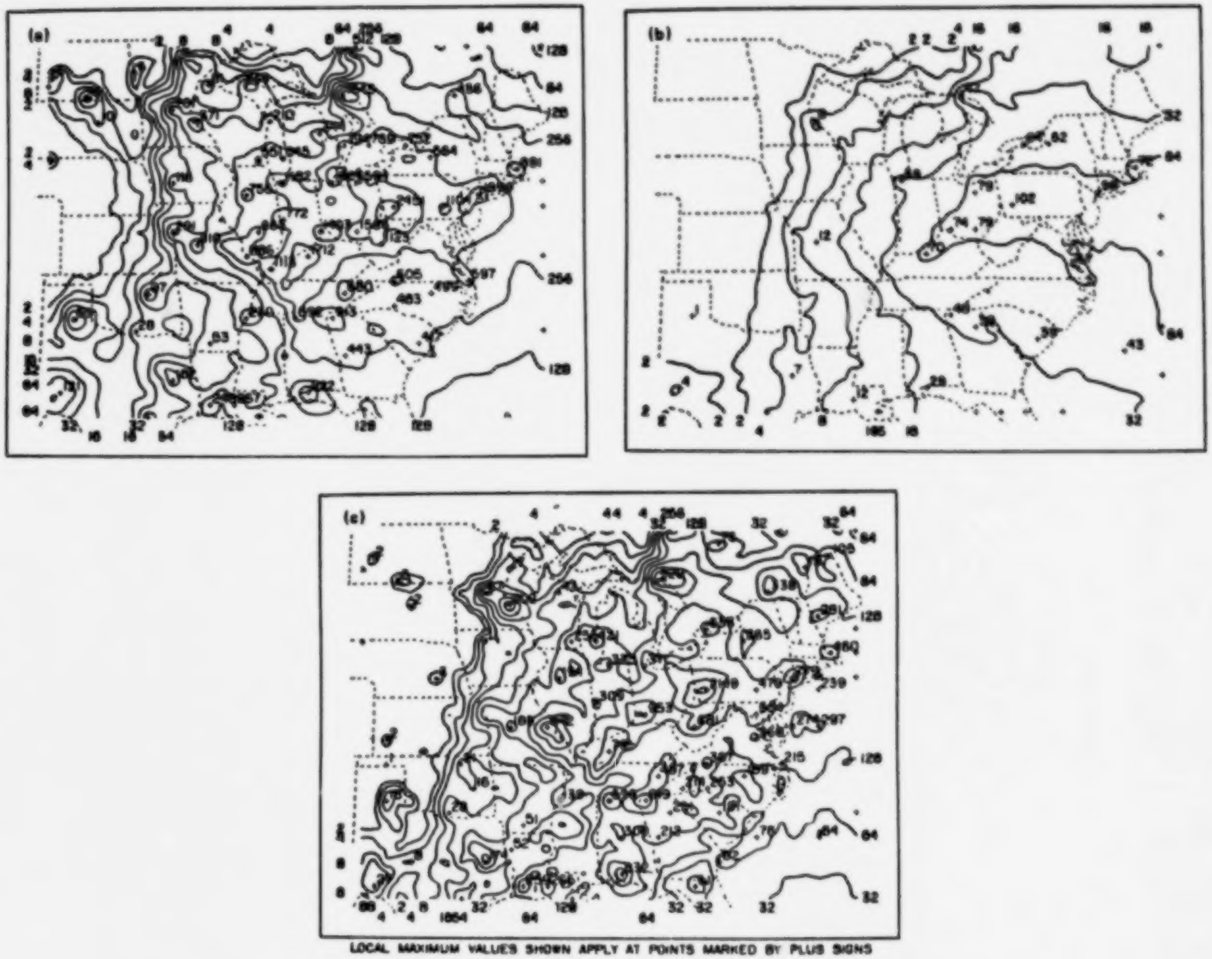
(a) $SO_2$ dry, (b) $SO_4^=$ dry, (c) $SO_2$ wet



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

JANUARY 1976 (mg/m$^2$)

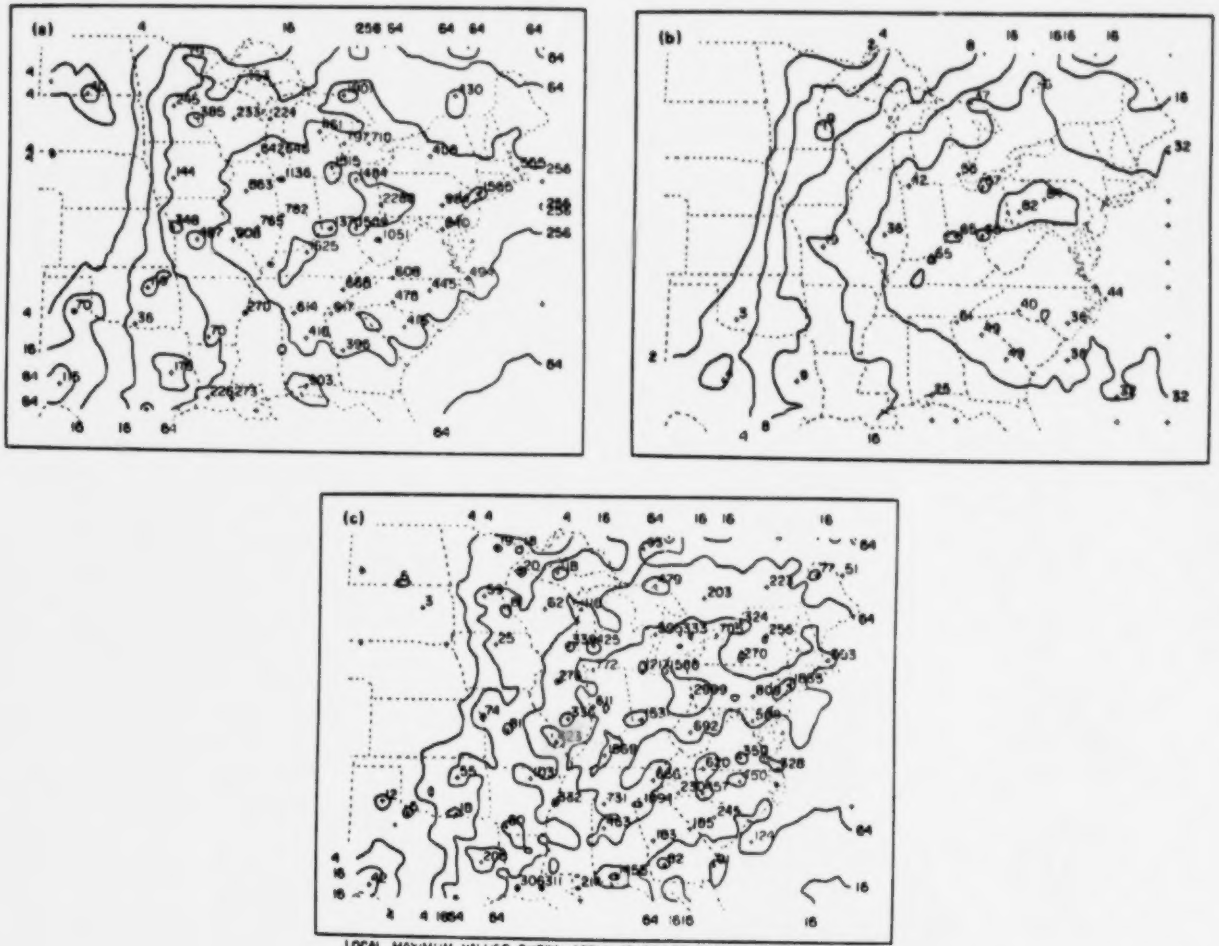
(a) $SO_2$ dry, (b) $SO_4^=$ dry, (c) $SO_2$ wet



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

JANUARY 1977 (mg/m$^2$)

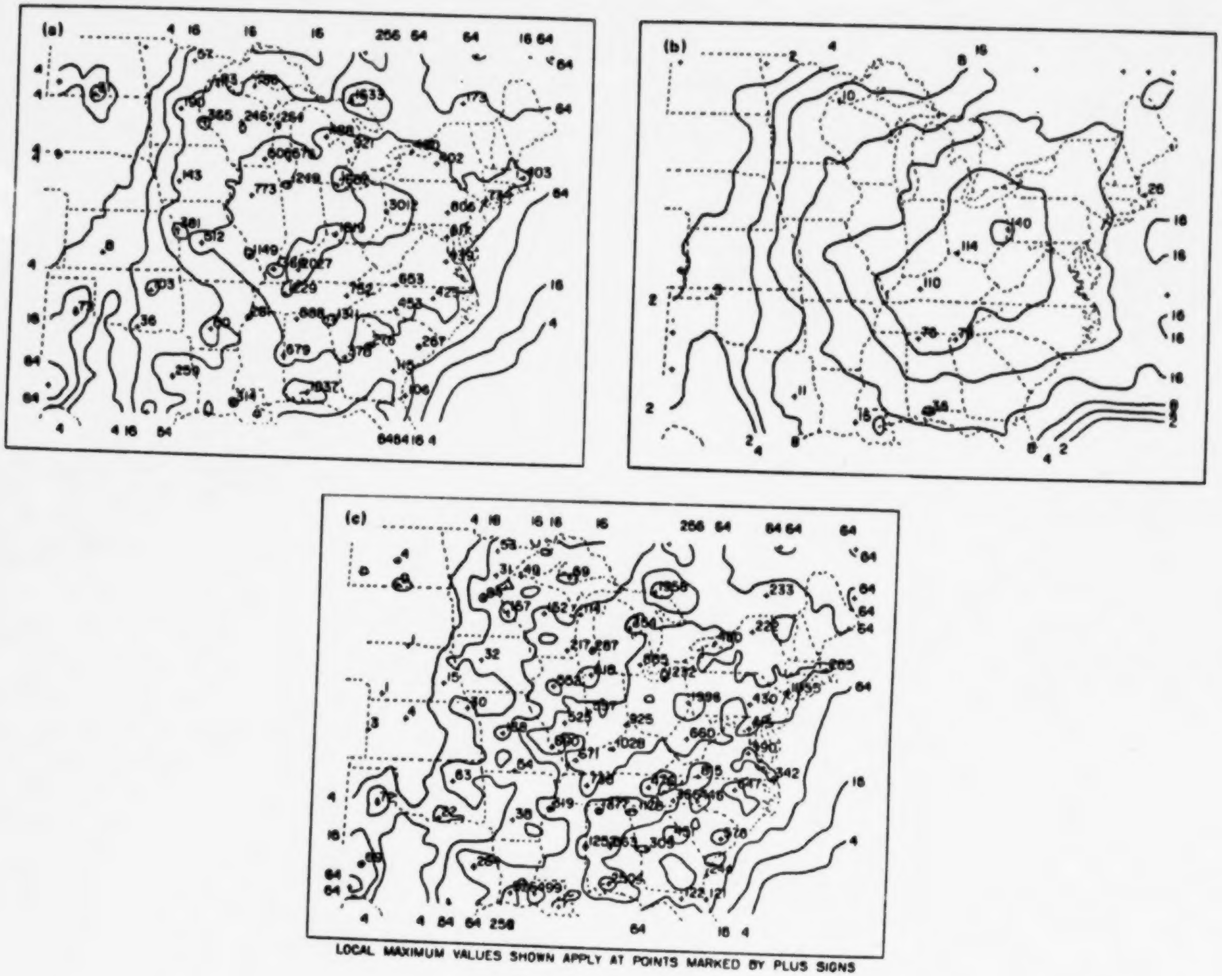
(a) $SO_2$ dry, (b) $SO_4^=$ dry, (c) $SO_2$ wet



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

JANUARY 1978 (mg/m$^2$)

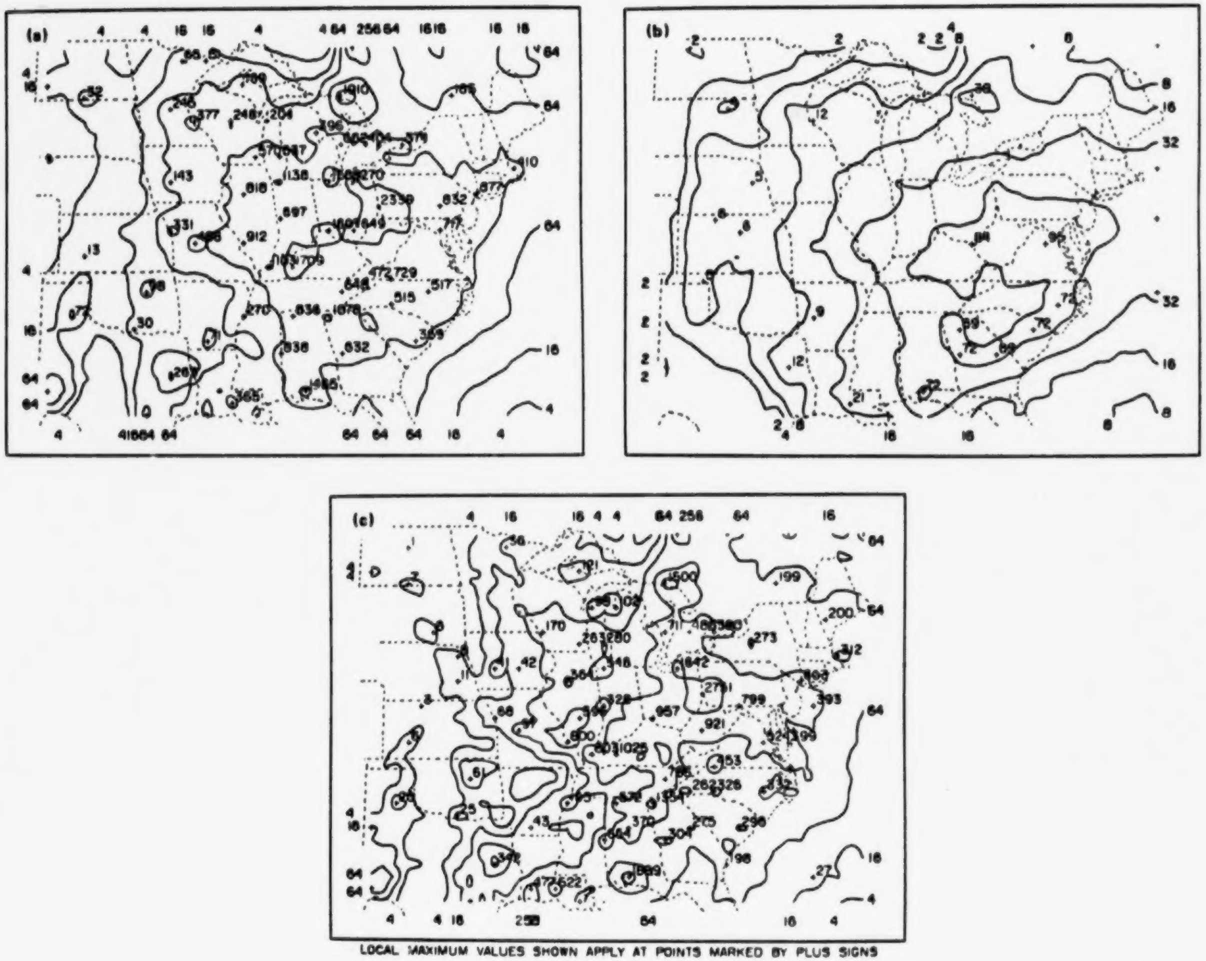
(a) $SO_2$ dry, (b) $SO_4^=$ dry, (c) $SO_2$ wet



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

JULY 1975 (mg/m$^2$)

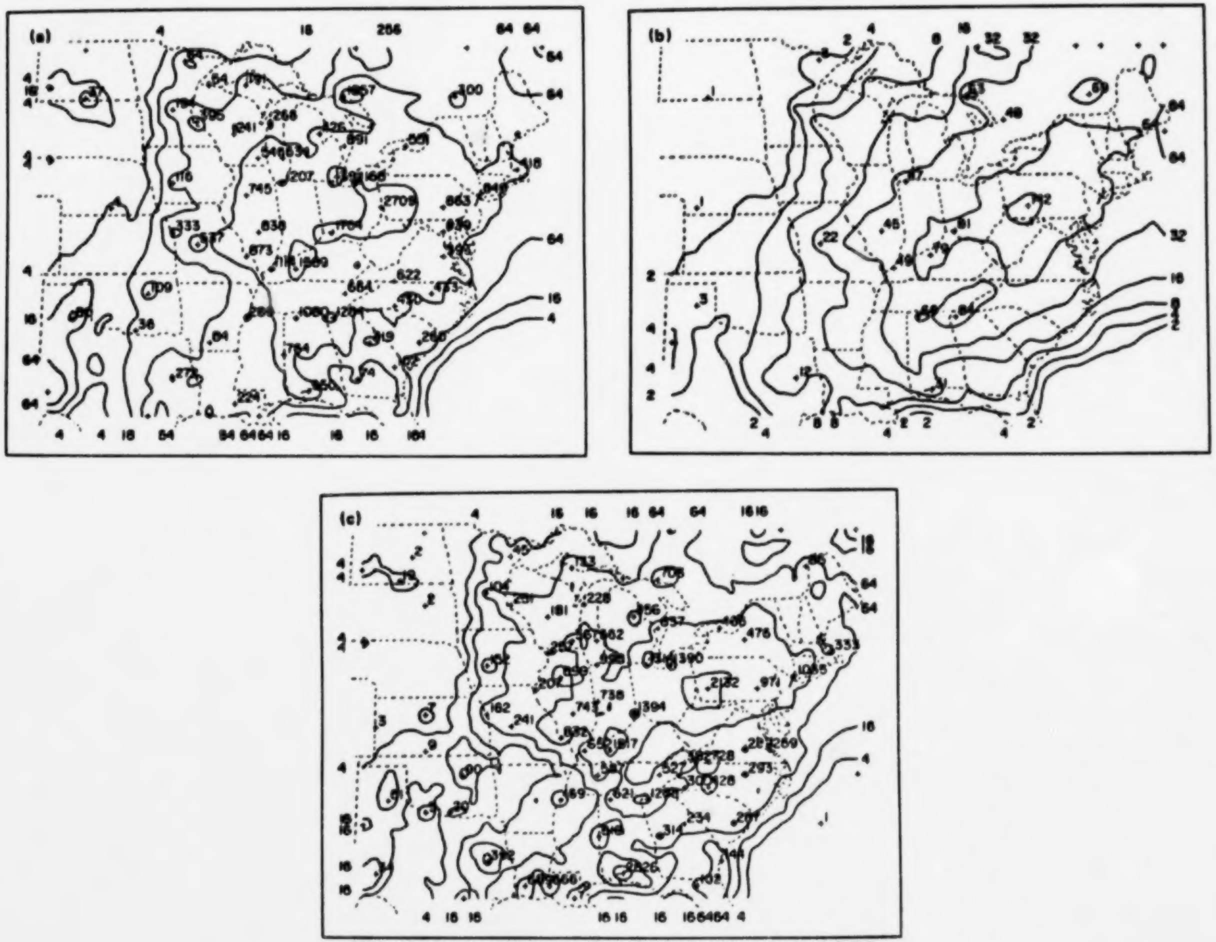
(a) $SO_2$ dry, (b) $SO_4^=$ dry, (c) $SO_2$ wet



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

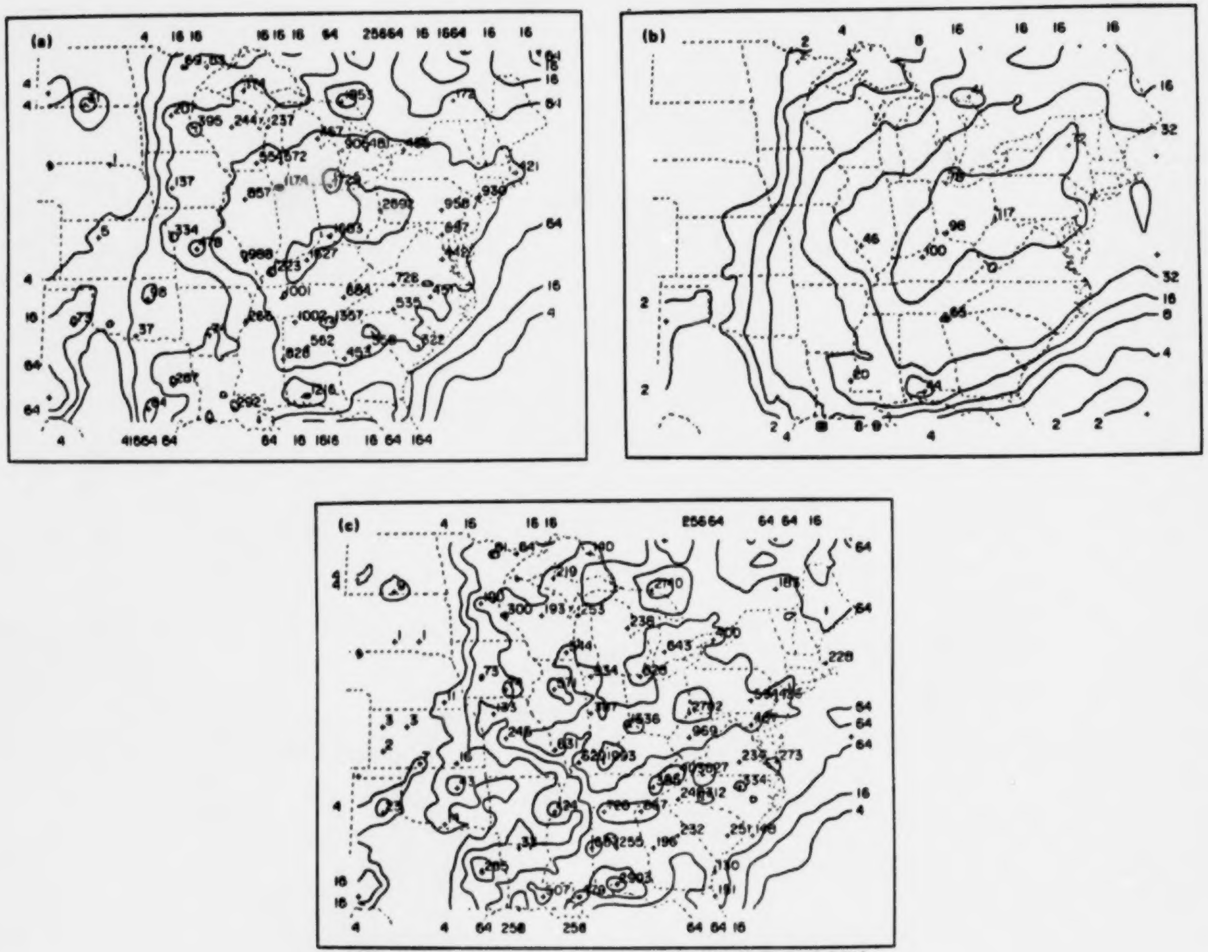
JULY 1976 (mg/m$^2$)

(a) $SO_2$ dry, (b) $SO_4^=$ dry, (c) $SO_2$ wet



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

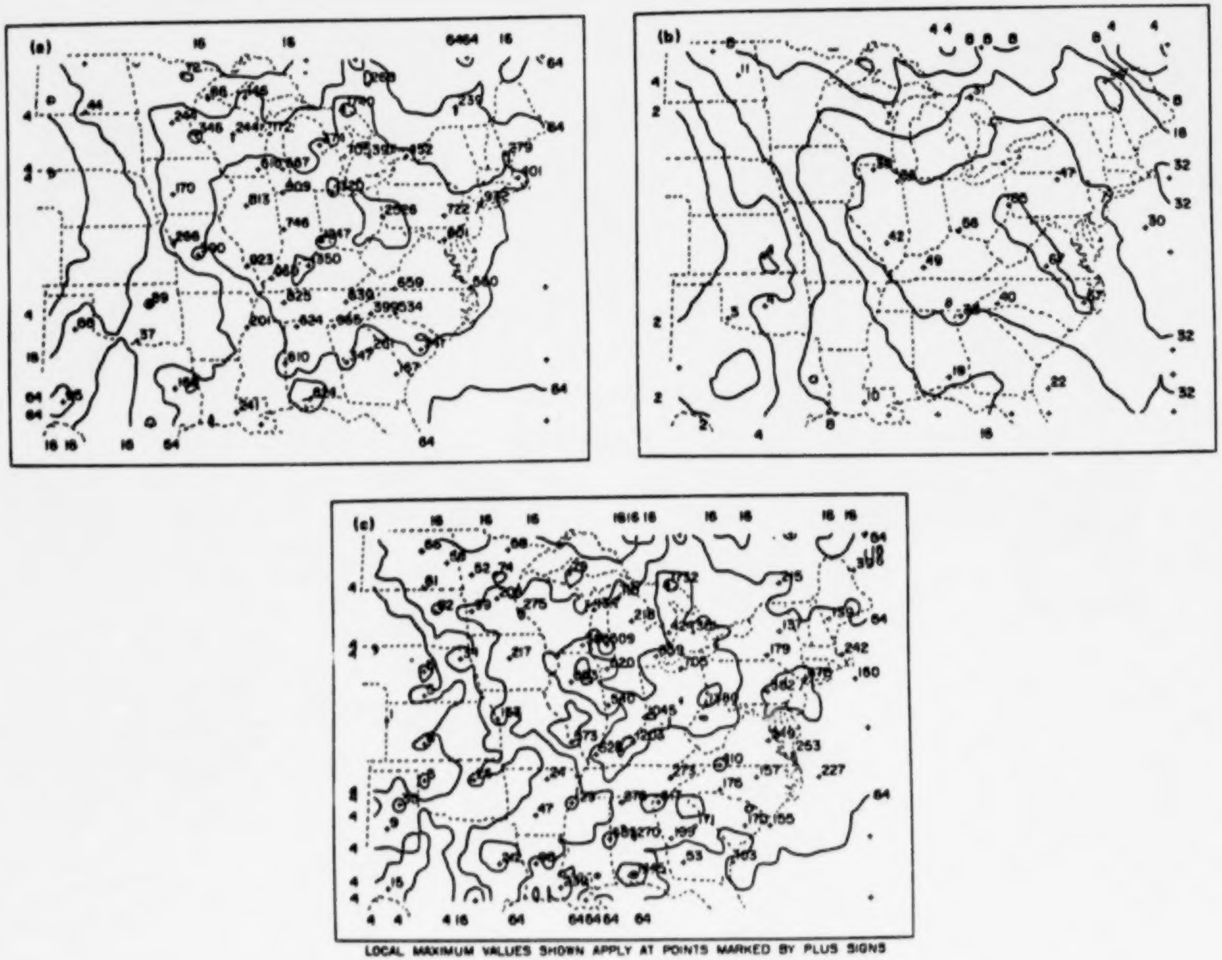
AUGUST 1977 (mg/m$^2$)
(a) $SO_2$ dry, (b) $SO_4^=$ dry, (c) $SO_2$ wet



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

JULY 1978 ($mg/m^2$)

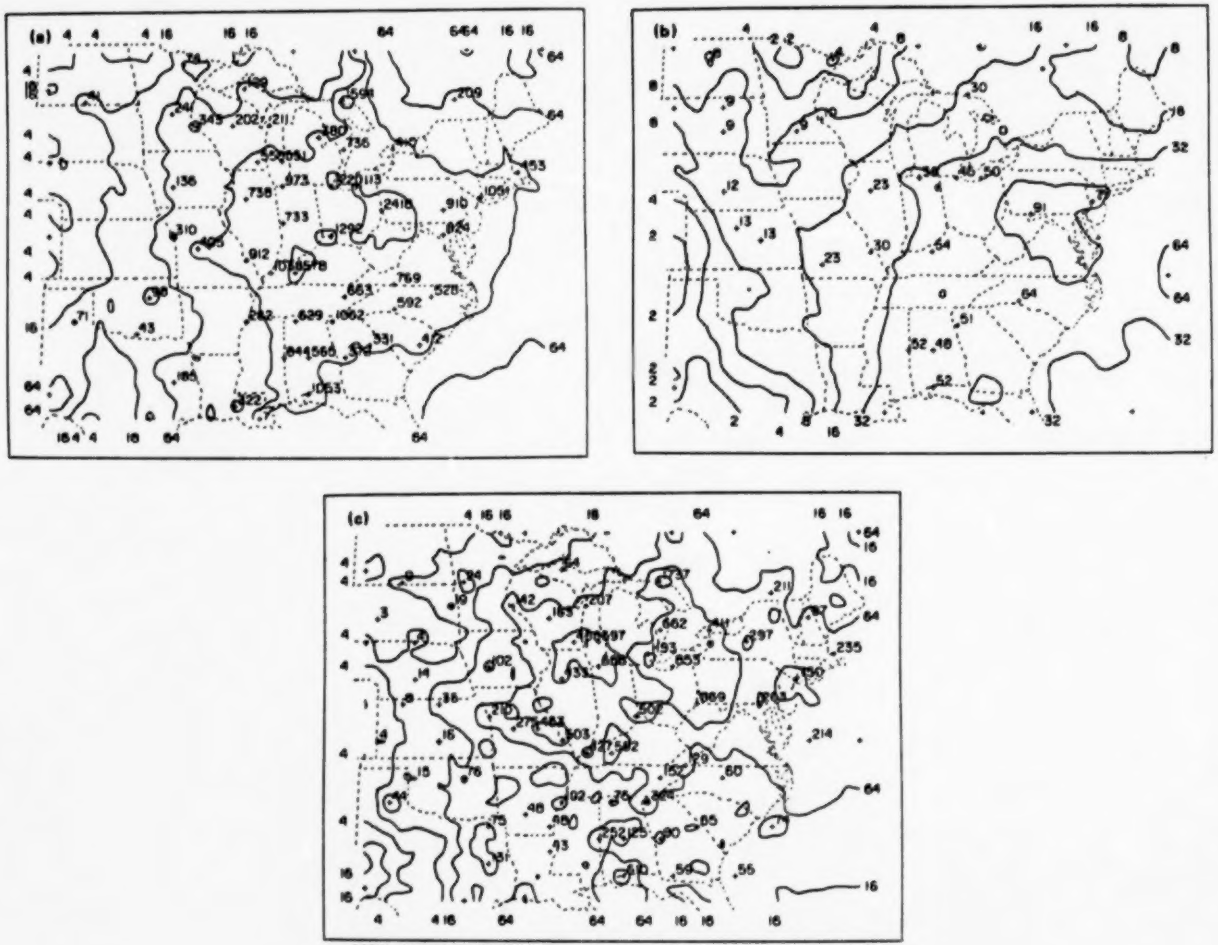
(a) $SO_2$ dry, (b) $SO_4^=$ dry, (c) $SO_2$ wet



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

APRIL 1975 (mg/m$^2$)

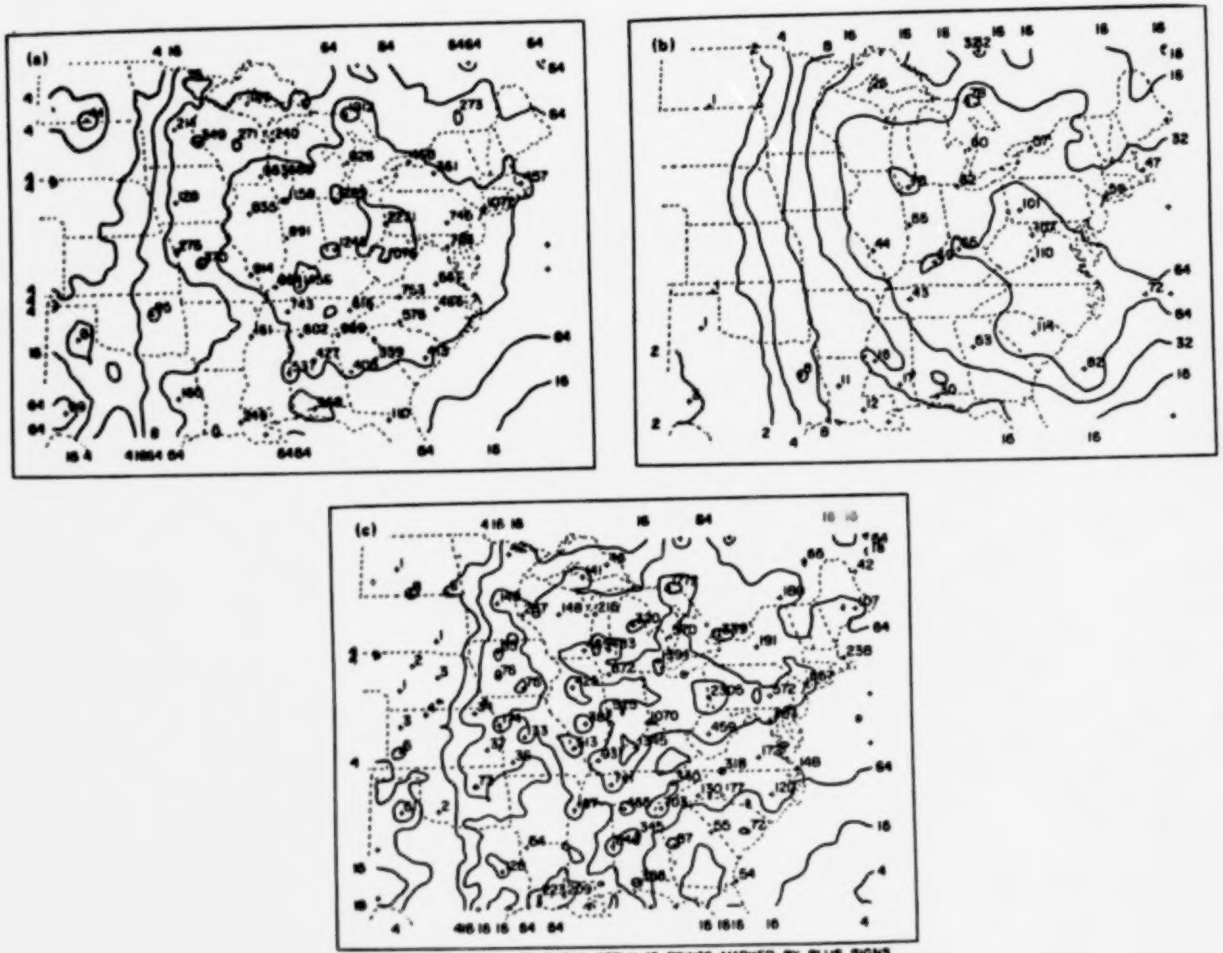
(a) $SO_2$ dry, (b) $SO_4^=$ dry, (c) $SO_2$ wet



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

APRIL 1976 (mg/m$^2$)

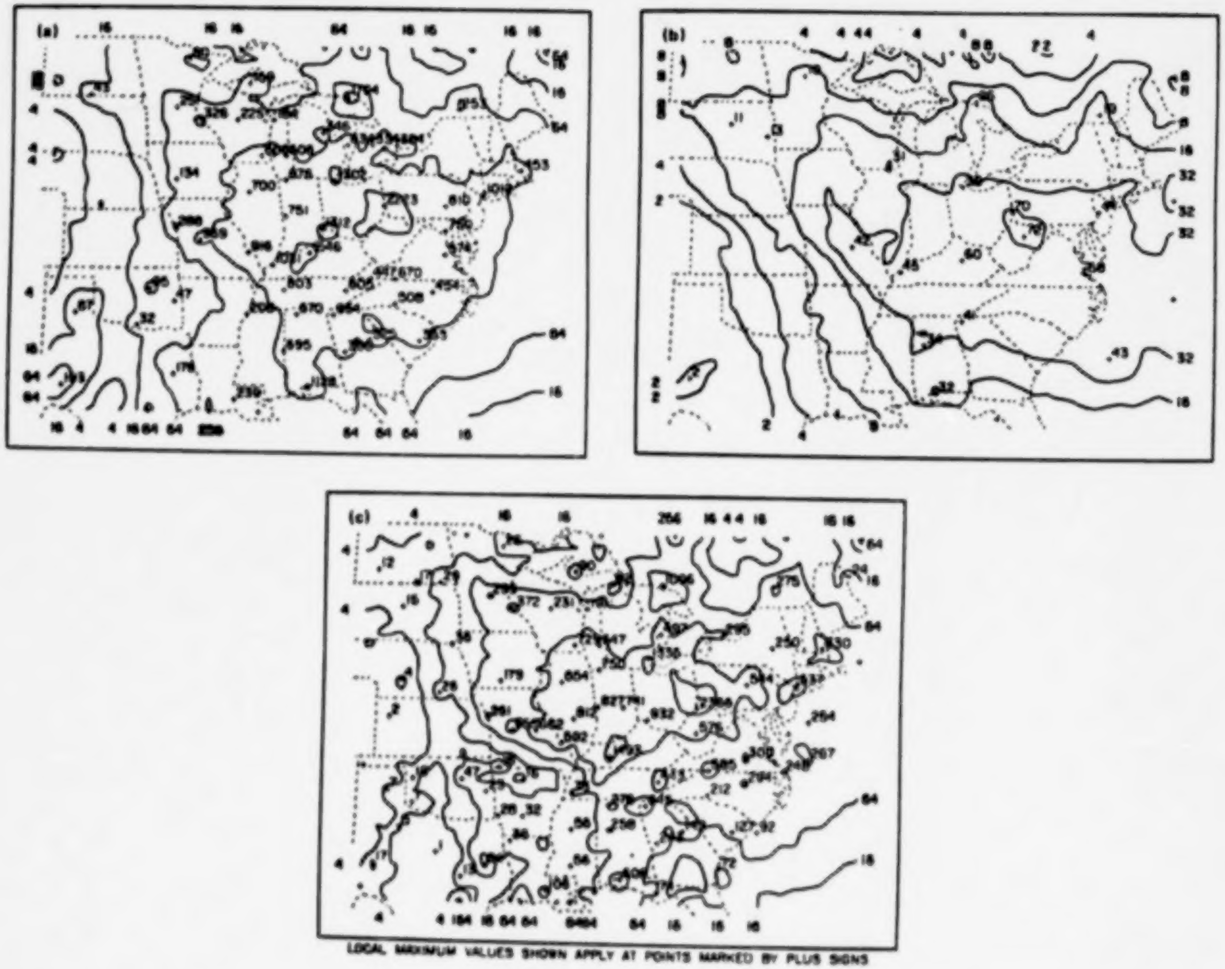
(a) $SO_2$ dry, (b) $SO_4^=$ dry, (c) $SO_2$ wet



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

APRIL 1977 (mg/m$^2$)

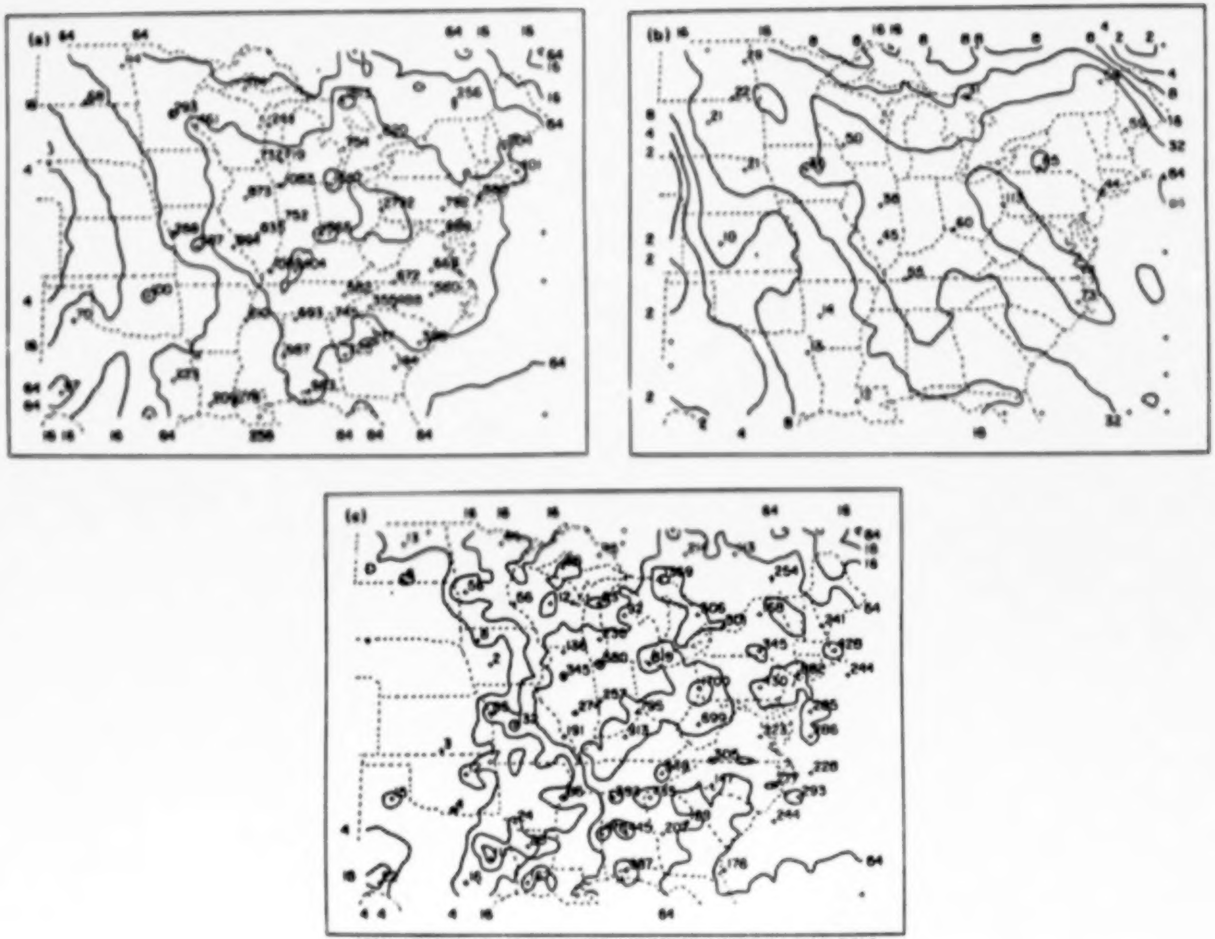
(a) $SO_2$ dry, (b) $SO_4^=$ dry, (c) $SO_2$ wet



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

APRIL 1978 (mg/m$^2$)

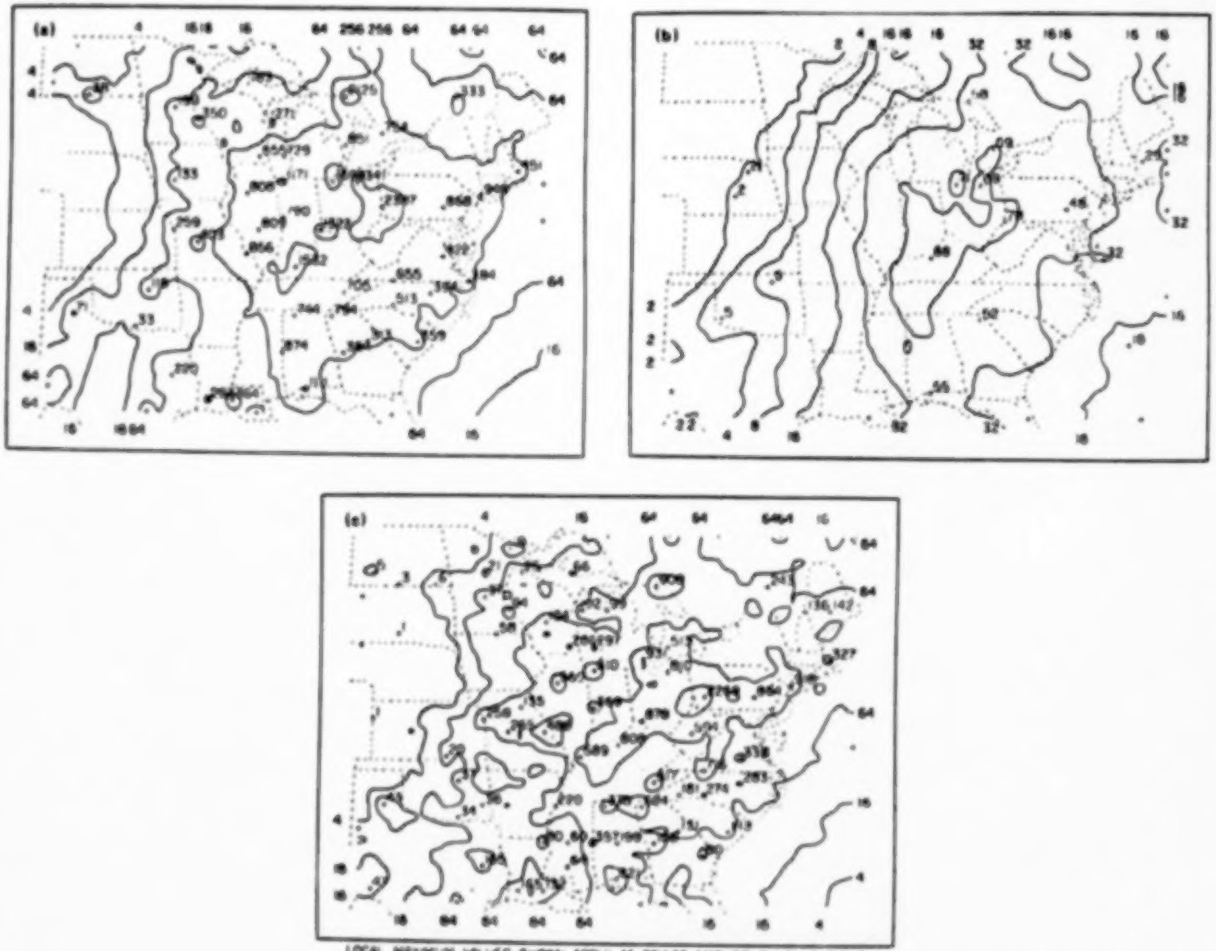
(a) $SO_2$ dry, (b) $SO_4^=$ dry, (c) $SO_2$ wet



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

OCTOBER 1975 (mg/m$^2$)

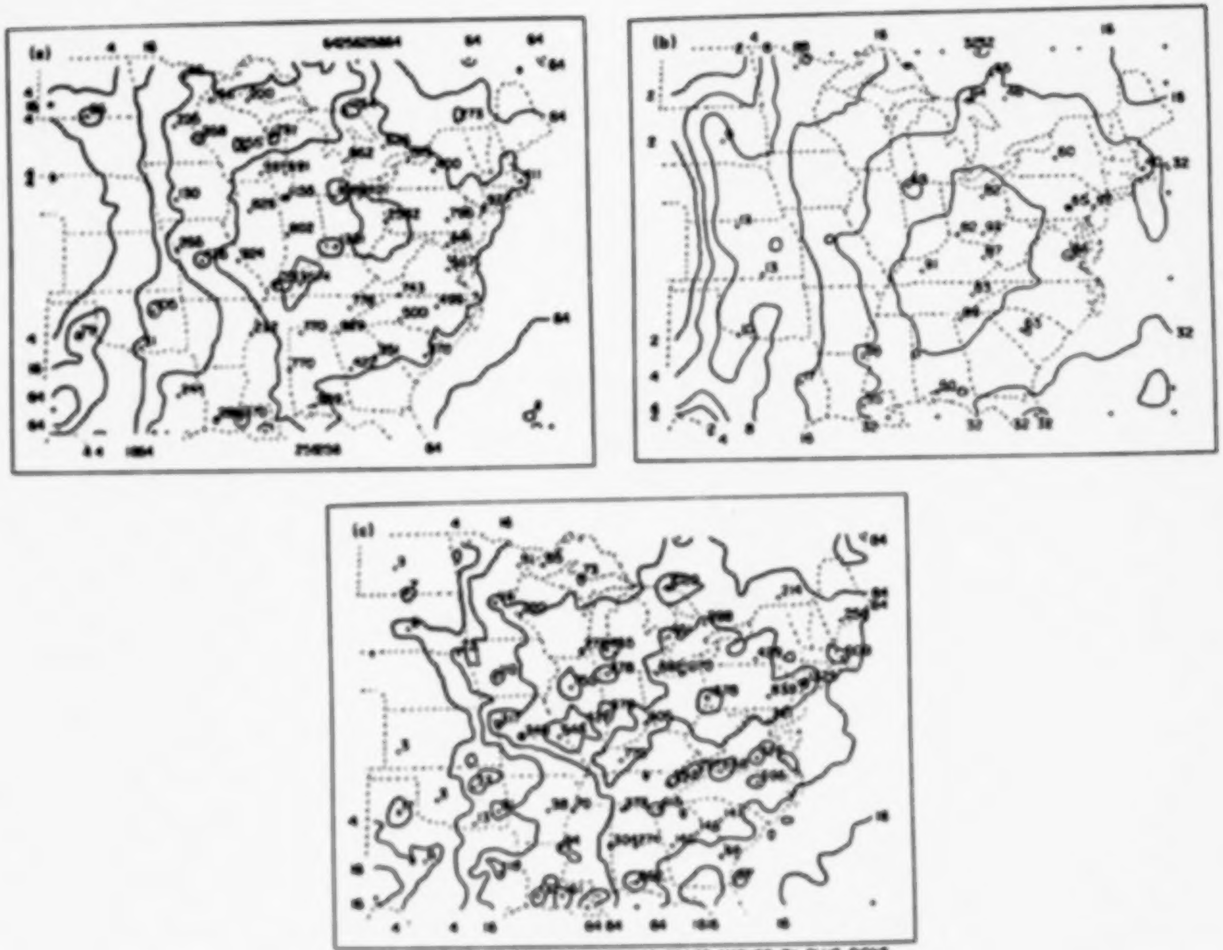
(a) $SO_2$ dry, (b) $SO_4^=$ dry, (c) $SO_2$ wet



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

OCTOBER 1976 (mg/m$^2$)

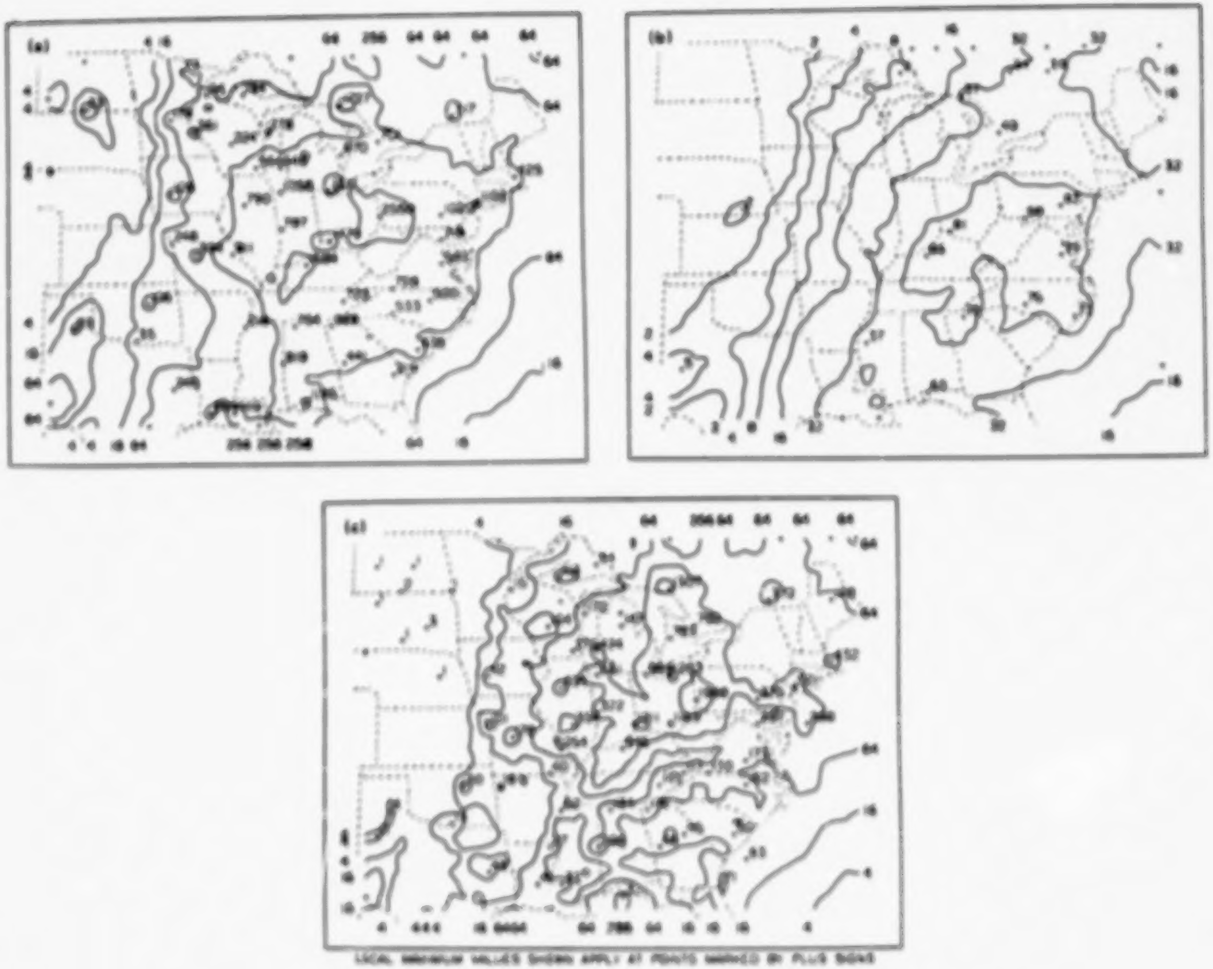
(a) $SO_2$ dry, (b) $SO_4^=$ dry, (c) $SO_2$ wet



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

OCTOBER 1977 (mg/m$^2$)

(a) $SO_2$ dry, (b) $SO_4^=$ dry, (c) $SO_2$ wet



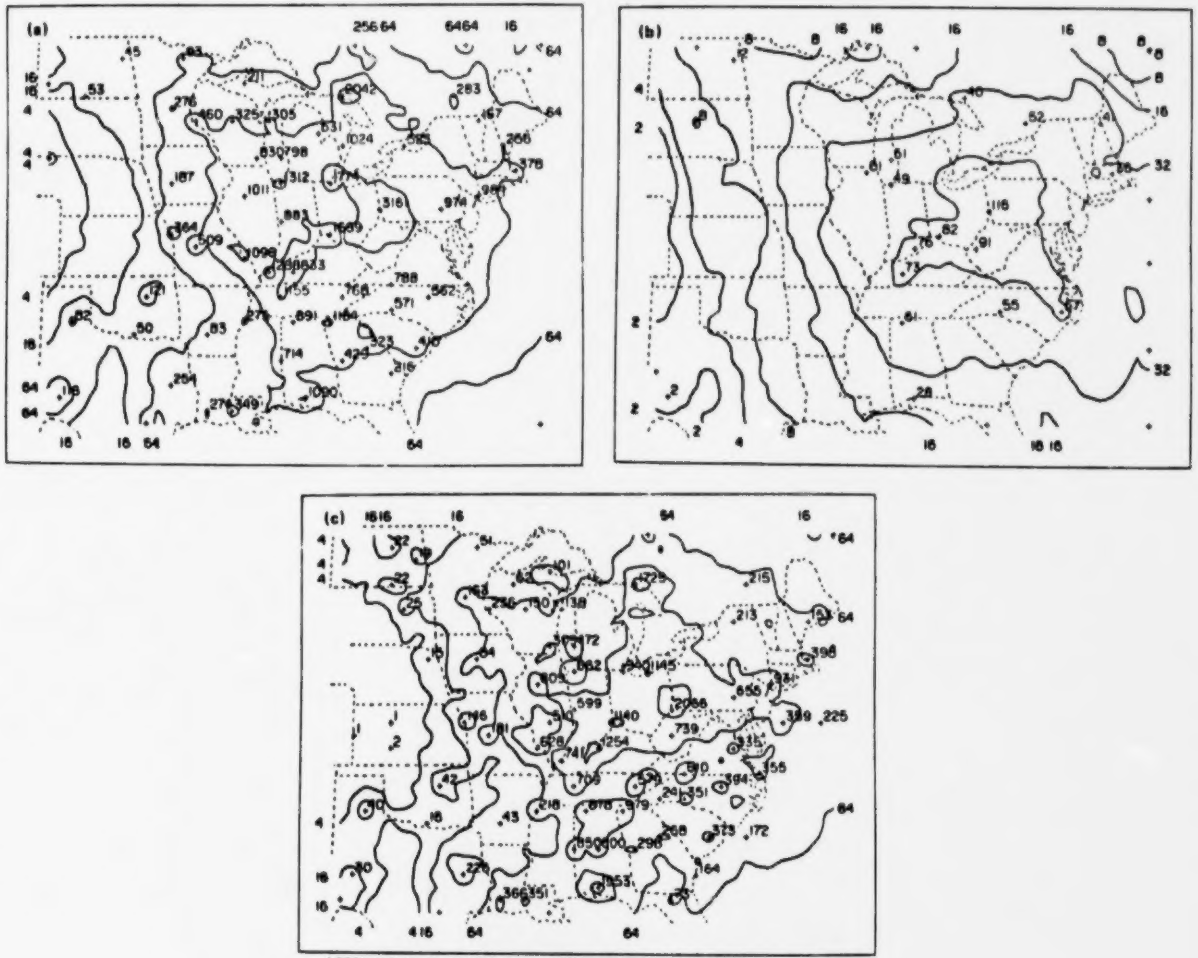
LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

OCTOBER 1978 ($mg/m^2$)

(a) $SO_2$ dry, (b) $SO_4^=$ dry, (c) $SO_2$ wet

# Appendix B

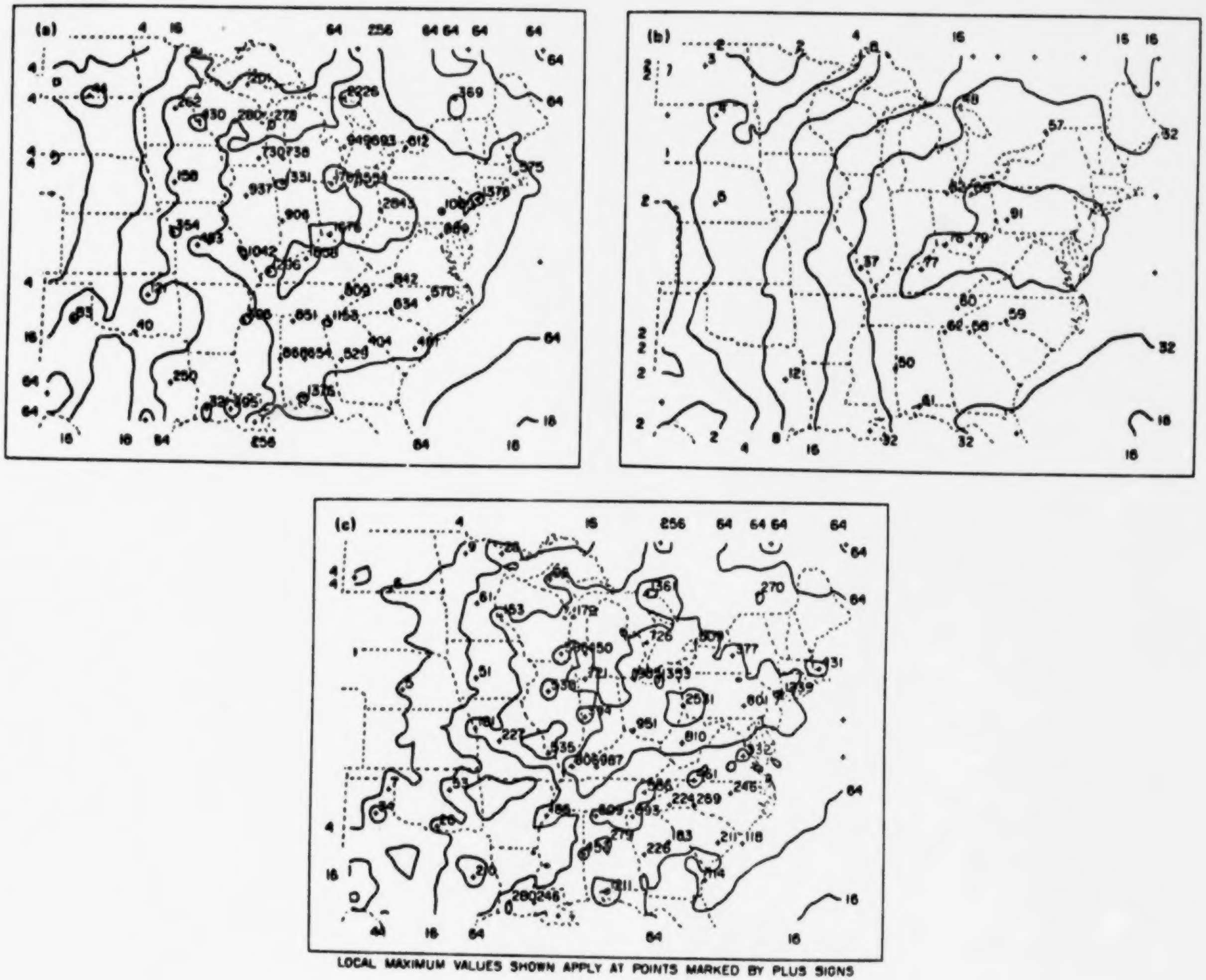
## CALCULATED ANNUAL RESULTS FOR $SO_2$ AND $SO_4^=$ DRY AND $SO_2$ WET DEPOSITIONS ($mg/m^2 \times 10$)



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

ANNUAL 1975 (mg/m$^2$ X 10)

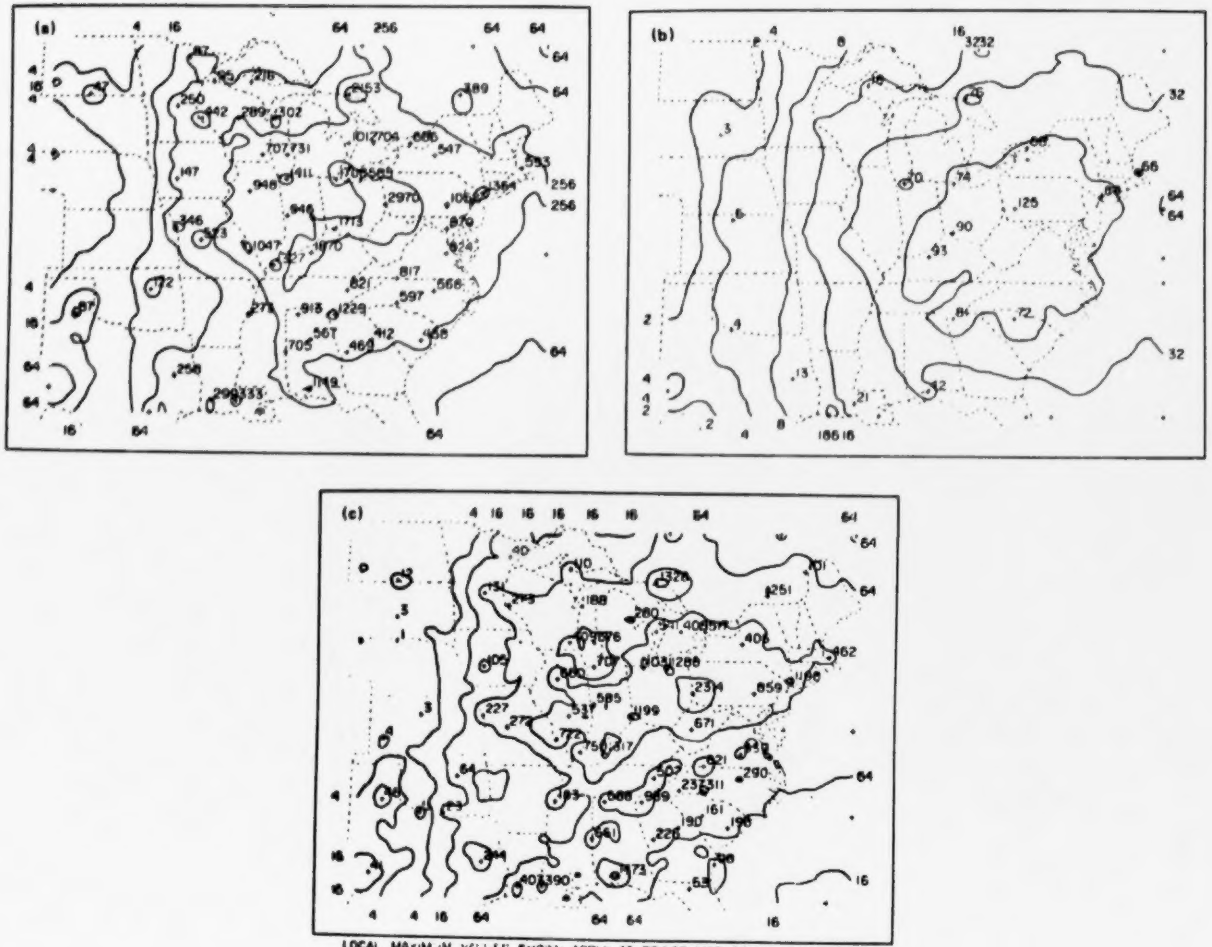
(a) $SO_2$ dry, (b) $SO_4^=$ dry, (c) $SO_2$ wet



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

ANNUAL 1976 (mg/m$^2$ X 10)

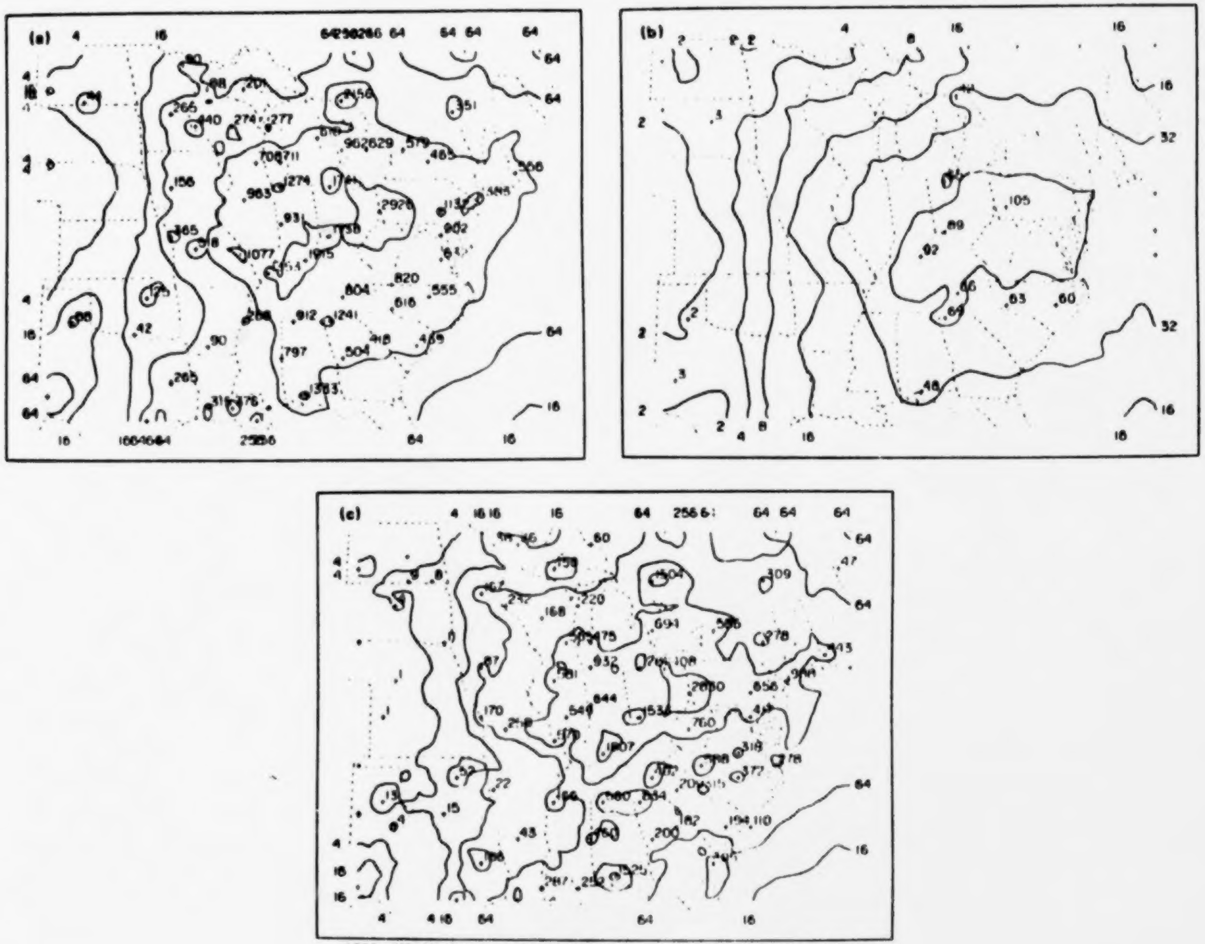
(a) $SO_2$ dry, (b) $SO_4^=$ dry, (c) $SO_2$ wet



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

ANNUAL 1977 (mg/m$^2$ X 10)

(a) $SO_2$ dry, (b) $SO_4^=$ dry, (c) $SO_2$ wet



LOCAL MAXIMUM VALUES SHOWN APPLY AT POINTS MARKED BY PLUS SIGNS

ANNUAL 1978 (mg/m$^2$ X 10)

(a) $SO_2$ dry, (b) $SO_4^=$ dry, (c) $SO_2$ wet